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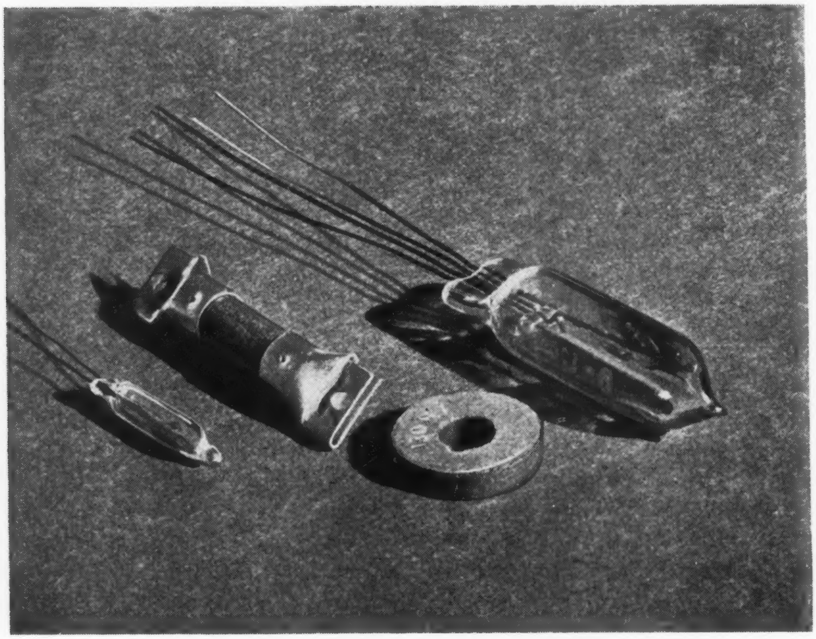
Racking experimental equipment in preparation for chromium plating.



Thermistors, Their Characteristics and Uses

By G. L. PEARSON
Physical Research

THERMISTOR is a contraction of the words "thermal resistor" and designates a new type of circuit element whose electrical resistance varies rapidly with change in temperature. In contrast with metals which have small positive temperature coefficients of resistance, thermistors are made from a class of materials known as semi-conductors which have relatively large negative coefficients.

The behavior of semi-conductors is not a new phenomenon; in fact, Michael Faraday, as early as 1834, reported measurements on the extremely high negative temperature coefficient of resistance of silver sulphide. Electric heating elements consisting of a mixture of rare earth oxides were developed by Nernst fifty years ago. These early devices, however, were not easily reproduced and did not have constant characteristics or long life.

The specific resistance versus temperature characteristics of three semi-conducting materials are shown in Figure 1. The upper curve is for uranium oxide (U_3O_8) which has a specific resistance of 50,000 ohm-cms at 0 degrees Centigrade. The specific resistance decreases rapidly with rise in temperature, being 2,800 ohm-cms at 100 degrees and 15 ohm-cms at 500 degrees Centigrade. The shape of this curve is typical of a large number of oxide semi-conductors. A mixture of nickel oxide (NiO) and manganese oxide (Mn_2O_3) shown in the next lower curve has a still larger negative temperature coefficient of resistance, the specific resistance values at 0 and 500 degrees Centigrade being respectively 10,000 and 0.8 ohm-cms. Silver sul-

phide (Ag_2S) exhibits a linear relationship between the logarithm of the specific resistance and the temperature below 179 degrees Centigrade. At this temperature a change in crystal structure occurs which decreases its specific resistance by a factor of about 70 and thereafter with increasing temperature the coefficient is slightly positive. The curve for platinum is plotted for comparison purposes; its temperature coefficient has a small positive value and the specific resistance is low, around 10^{-5} ohm-cms.

There are three common ways of using thermistors in electric circuits. In the first or externally heated method, the resistance of the thermistor is controlled by the ambient temperature. The second or directly heated method allows the electric current in the circuit to pass directly through the thermistor, thus heating it and changing the impedance in the circuit. The third or indirectly heated method uses a thermistor having a separate heating coil placed in a controlling circuit; the heat generated in it regulates the thermistor resistance. Thermistors suitable for each of these three circuit uses are shown in the headpiece. An ambient temperature-controlled thermistor is second from the right. The two units at the left are directly heated devices. The one enclosed in the insulating tube with metal electrodes at either end is a completed Western Electric 1A thermistor, while the other is the internal structure of the 1A. The unit farthest to the right with four lead wires is an indirectly heated thermistor.

The resistance versus power characteristics of a typical Western Electric 1A thermistor which is made of uranium oxide are shown in Figure 2. This is a static curve since for each point sufficient time is allowed so that the resistance attains its steady value. At room temperature and low power the resistance is 78,000 ohms. An increase in power, however, heats the unit and lowers its resistance until at ten milliwatts the value is approximately 30,000 ohms and at 100 milliwatts only 400 ohms.

The static voltage versus current curve for this same thermistor is shown by the solid curve in Figure 3. At low current where Ohm's law is obeyed the plot is a straight line, having a slope of forty-five degrees. As the current is increased, however, the slope decreases until at about one milliampere the voltage reaches a

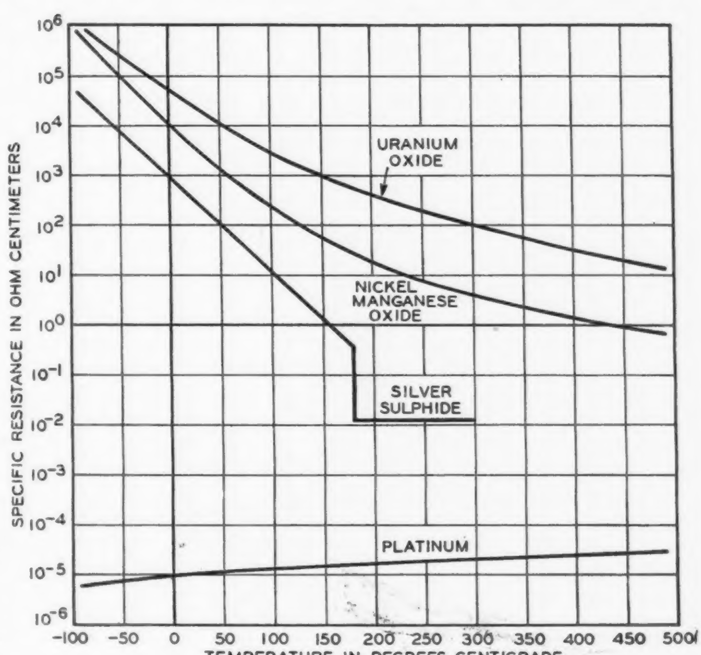


Fig. 1—Resistance versus temperature characteristics for three thermistor materials and for a metal

maximum and thereafter decreases as the current is increased. The falling portion of the curve, therefore, exhibits a negative resistance characteristic. At currents beyond 100 milliamperes the voltage drop in the semi-conductor as shown by the dotted

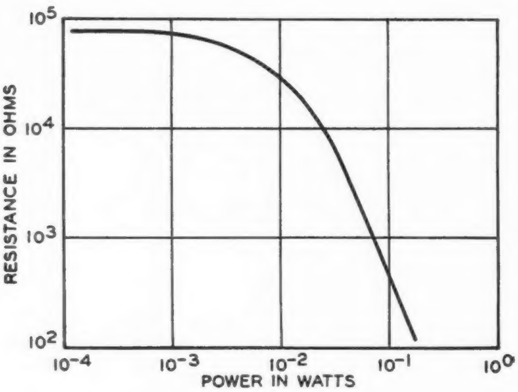


Fig. 2—Resistance versus power characteristic of directly heated thermistor

line C has become so small that it is the same order of magnitude as the voltage drop in the metal lead wires, indicated by the dotted line D. The solid curve, which is the sum of these two voltages, thus has a second point of inflection and its slope becomes positive again. Although this curve is extended to ten amperes for analysis purposes, the 1A thermistor cannot carry currents greater than fifteen milliamperes continuously without impairing its life. It should be pointed out that thermistors made of silver sulphide or uranium oxide are usable only in alternating-current circuits since continued passage of direct current produces a polarization with an accompanying large increase in electrical resistance. Nickel manganese oxide does not polarize and is therefore equally stable in either a-c or d-c circuits.

In order to determine the life of 1A thermistors they have been placed in a circuit where an off-and-on current cycle of ten milliamperes a-c has been repeated every thirty seconds over an extended period of time. Resistance measurements were made on the units periodically in order to determine their stability with time. Figure 4 shows the results on a typical unit whose initial resistance at 76 degrees Fahrenheit is 62,000 ohms. The general trend is a rise in resistance during the first part of its life, after which it becomes quite constant. Over a period of fifteen months, during which time the thermistor was put through 650,000 heating cycles, the cold resistance did not vary more than seven per cent. The resistance of the thermistor when hot was found to be equally stable.

If a directly heated thermistor is placed in series with a source of voltage, key, milliammeter, and protecting resistance as shown in Figure 5, the meter will show a delayed building-up of the current following closure of the key due to the thermal capacity of the thermistor. This delay is illustrated by the current versus time curve for a typical 1A thermistor. The initial current, which is determined by the cold resistance of the thermistor, is small and rises slowly at first, then

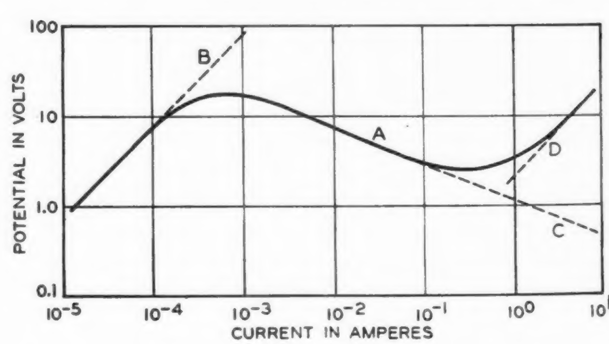


Fig. 3—Voltage versus current characteristic of directly heated thermistor

more rapidly as the thermistor becomes hot. The final current is limited by the circuit resistance. The magnitude of the time delay amounts to about one-half second for the particular circuit conditions shown in Figure 5; it increases with decrease in battery voltage. By a suitable design of the thermistor and choice of circuits it is possible to vary this time delay from a few milliseconds to several seconds. This time-delay property of thermistors is a distinct advantage in many applications since it provides an action which if obtained by other techniques would undoubtedly be much more cumbersome and costly.

Directly heated thermistors capable of carrying much larger currents than fifteen milliamperes, the maximum continuous current rating of the 1A thermistor, have been made by pressing semi-conducting materials into discs in much the same way that silicon carbide varistors are formed. These may also be made in the same shape as the ambient temperature-controlled unit shown in the headpiece. Such thermistors have characteristics of the same form as the 1A but can carry currents of several amperes. Due to their large thermal capacity they have longer heating and cooling periods when used as time-delay devices.

The thermistors which have been described have all been of the directly heated variety. By placing a heating coil around the thermistor in such a way that it is insulated electrically but in contact thermally, an indirectly heated device is obtained. The thermistor resistance as a function of heater current for a unit made of a silver sulphide semi-conductor with a 100-ohm heating coil is shown in Figure 6. With no current flowing the resistance is one megohm, at ten milliamperes it is 10,000 ohms, and at fourteen milliamperes the resistance is eight ohms. The curve flattens at this point because of the change in crystal structure of the silver sulphide. The thermistor resistance thus changes by a factor of 100,000 for a power dissipation of only twenty milliwatts. This curve is completely reversible. Indirectly heated units made of a mixture of nickel and manganese oxides have excellent life characteristics but do not cover such a wide resistance range with small heater powers.

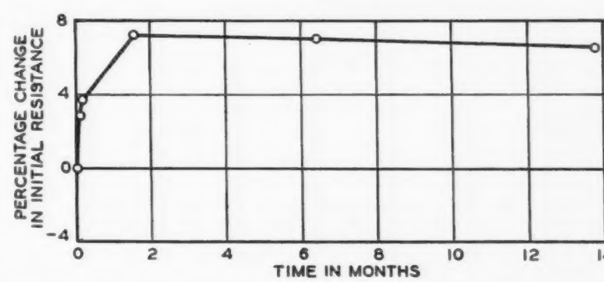


Fig. 4—Life characteristic of typical 1A thermistor

The thermal and electrical characteristics of thermistors suggest a large number of circuit applications. One obvious use for devices having such high temperature coefficients of resistance is that of a resistance thermometer. In this application the measuring current is kept so low that it produces no appreciable heating and the thermistor resistance is dependent only on the ambient temperature. At 25 degrees Centigrade the changes in resistance of uranium oxide, nickel manganese oxide, and silver sulphide are respectively 3.0, 4.2 and 4.9 per cent per degree Centigrade change in temperature. This compares with 0.35 per cent per degree Centigrade for platinum. A second use for

thermistors is that of compensating for changes in resistance due to ambient temperature in circuits having a positive temperature coefficient of resistance. This is accomplished by associating the thermistor with series or parallel circuit elements so that the change in resistance with temperature of the combination is equal and opposite to that of the remainder of the circuit which it is necessary to compensate.

The resistance versus power characteristics of thermistors make them useful as sensitive current and power-measuring devices. Due to the extremely small electrical capacity associated with these devices they are suitable for use in either low or ultra-high-frequency circuits. When placed in the proper bridge circuits thermistors may be used as flow meters, vacuum gauges, or to measure other physical quantities dependent on the flow of thermal energy from a hot body. High-sensitivity bolometers for the measurement of radiant energy have been constructed using directly heated thermistors for the temperature-sensitive element.

Thermistors may be used to stabilize the output voltage in circuits in which the input voltage varies over a considerable range. As shown by the voltage current plot in Figure 3, the thermistor voltage decreases with increase in current over the central portion of the curve. If a suitable chosen value of ohmic resistance is placed in series with the thermistor, the voltage across the combination may be held practically constant in this current range. The series combination of thermistor and resistance will therefore act as a variable current shunt if placed in parallel with the load and will tend to maintain the load voltage constant. Although changes in temperature limit the accuracy of regulation, these errors can be kept to a minimum by operating the thermistor at temperatures well above ambient.

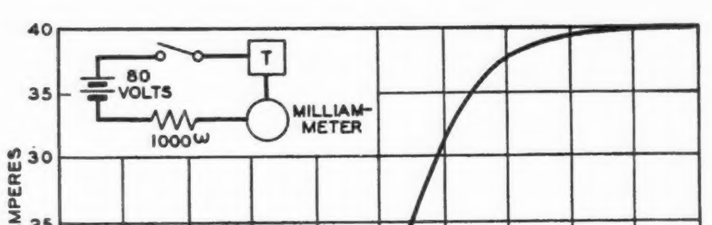


Fig. 5—Current versus time characteristic of a directly heated thermistor

The negative resistance characteristic exhibited by directly heated thermistors suggests their use as generators of alternating voltages. The inherent thermal capacity, however, limits their usefulness to relatively low frequencies. Tiny thermistors designed especially for this purpose have been made to oscillate, when placed in an appropriate resonant circuit, over the entire voice-frequency range. The output power is around one milliwatt and, although the character-

istics are not extremely stable, these thermistors have been operating for over two years in a continuous life test circuit without serious signs of deterioration.

A standard relay may be made into a slow-acting device by putting a directly heated thermistor in series with its winding. The magnitude of the delay depends on the thermistor characteristics, the relay constants, and the circuit conditions. False operations of relays resulting from high voltage surges may be prevented in this manner. The thermal inertia of the thermistor, together with its high initial resistance, discriminates against voltage surges of short duration, but an application of voltage of greater duration, even though of lesser magnitude than the surge voltage, operates the relay after a small delay. This is the application for which the 1A thermistor was designed and a large number of these units have already been installed in the telephone plant, primarily in ringing circuits for private-branch exchanges.

Indirectly heated thermistors may be used as variable resistance devices which are operated by an electric current through the heating coil rather than by a sliding contact as in a standard rheostat. These devices have the advantage that their resistance change is continuously variable and that they may be operated electrically from a distant point. This type of thermistor has found important applications in automatic transmission-regulating networks.

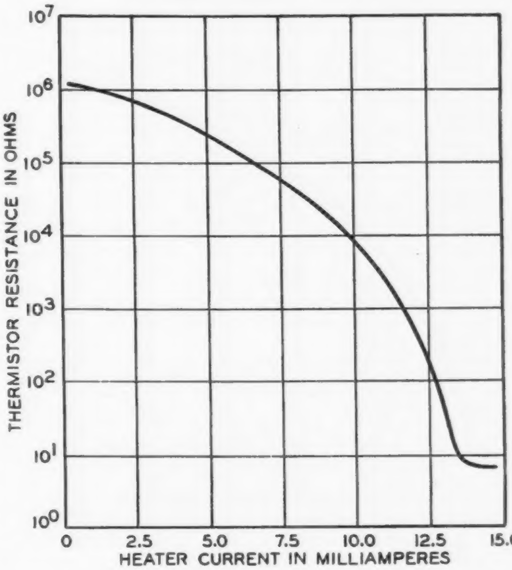


Fig. 6—Resistance versus heater-current characteristic of an indirectly heated thermistor which was made of silver sulphide

Thermistors have already found important applications as circuit elements. As time goes on, further uses will undoubtedly be found for these simple and inexpensive devices.

Devices for Combining DB Levels

By K. G. VAN WYNEN
Transmission Development

A FREQUENT operation in transmission studies is to total the contributions made by two or more sources when the quantities are expressed in decibels. Examples are finding the combined level of several noise sources or integrating the components of a complex tone. These computations are time-consuming by ordinary methods, if there are many components, and they are subject to inherent errors due to misplaced decimal points. The labor-saving devices described here have been developed to obtain results more quickly and to reduce errors when many computations have to be made.

The quantities involved in these examples are usually expressed in db with respect to a chosen reference power P_0 by the formula $db = 10 \log_{10} (P/P_0)$. If the components combine on a power basis, the resultant level in db is determined by the sum of the component powers. The mathematical process, therefore, consists in finding P/P_0 for each component, adding, and reconverting to the db scale. Suppose two components measure 53 db and 49 db above the reference level; then by the above equation 53 db corresponds to a power ratio of 2×10^5, and 49 db to 8×10^4, or 0.8×10^5. The sum is 2.8×10^5, which represents a level of 54.5 db. This requires, besides division and addition, the finding of both logs and antilogs. Whether the computations are done by log

tables or slide rule, it is time-consuming and subject to error, particularly if the components are numerous and cover a wide range.

If two components are equal in magnitude their combined level is 3 db higher than the components whatever the original levels were. This follows from a fundamental property of the db scale; adding two equal powers is equivalent to multiplying by 2, which represents a 3-db increase in power. Similarly, adding two components which differ by 3 db is equivalent to multiplying the higher of the two powers by 1.5, or adding 1.8 db to the higher level, regardless of the absolute levels. Thus for any two components which combine on a power basis, there exists a unique increment which, added to the level of the higher component, gives the level of the combination. This increment is a function only of the difference between the two component levels; if the difference is 0, the increment is 3 db, and if more than 20 db, the increment becomes quite small. These increments are shown graphically in Figure 1 as a function of the difference of level.

This curve, or a table based on it, is a convenient method for combining two components. When three or more components are to be added, the operation is performed stepwise, by combining two components and then the third with the "sum,"* and similarly each additional component with the progressive "sum." It makes no difference in what order the components are added. When there are many components, this process becomes tedious because each succeeding component must be subtracted from the progressive "sum" to find the increment to be added.

This procedure can be mechanized readily in several ways, by using special slide rules. The one shown in Figure 2 is the closest analogue of the mathematical process just described. It has special linear scales on an ordinary 10-inch slide rule, and an indicator capable of crosswise as well as lengthwise motion. This indicator is made of transparent material, and has inscribed on it not only the usual vertical index line, but also a straight line inclined at 45 degrees, and a curved line like that of Figure 1 plotted in appropriate units along the vertical line. The origin is at the intersection of the two straight lines.

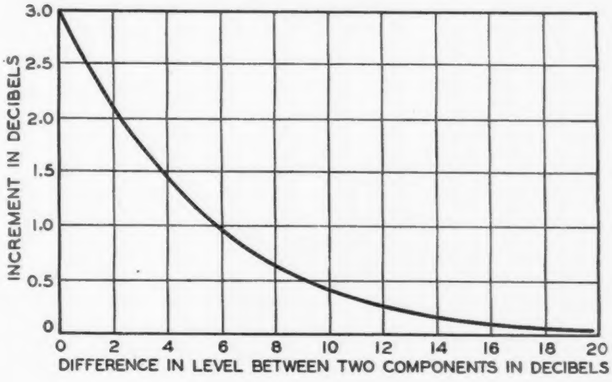


Fig. 1—This curve shows the amount in db by which the combined power level of two components exceeds the higher of the two

In one method of using the rule, the vertical line is set on the lower scale at the higher of the two components to be combined. By moving the transparent indicator vertically the 45-degree line can be made to intersect this scale at a point corresponding to the lower of the two components. The

*The word "sum" will hereafter mean the db figure representing the level resulting from the combination of two or more components whose levels are also expressed in db.

increment will then be found added to the higher component where the curved line intersects this scale. For example the components shown in the photograph are 12 and 10, the increment is 2.1, and the "sum" is 14.1, which is the final answer for these two components. If other components are to be added, the vertical line is shifted to the "sum," and the operation repeated for each component. To avoid having to remember the "sum" while shifting the indicator, the arrow index on the otherwise blank slide is shifted to mark the "sum," and the vertical line is then shifted to the arrow. Both plus and minus scales have been provided to cover the complete range.

To avoid the cross-sliding indicator with its inscribed curve the device shown in Figure 3 was developed. This slide rule has the same scales as that in Figure 2 and a glass indicator with a single cross-hair. The increments in Figure 1 are inscribed on the slide by broken lines extending from the bottom to the top of the slide and numbered to correspond to the db difference between the components to be added. The indicator has been removed from the array of broken lines in Figure 3 to give a clear picture. If the components are −20 and −30 the glass indicator cross-hair is set at −20, and the zero of the lower part of the slide scale at −30, as shown. The broken line labeled 10 would be under the cross-hair, at its lower extremity. The cross-hair is then moved to the right until it is set on the upper extremity of the broken line numbered 10. The answer with the proper increment added is the scale reading under the cross-hair. This follows because the displacement of the upper end of each broken line is equal to the increment for the corresponding difference in level between the two components to be added. The broken lines to the left of zero on the slide are engraved in red instead of black and are used when components are to be subtracted instead of added.

The scale at the right of the slide permits the rapid combination of

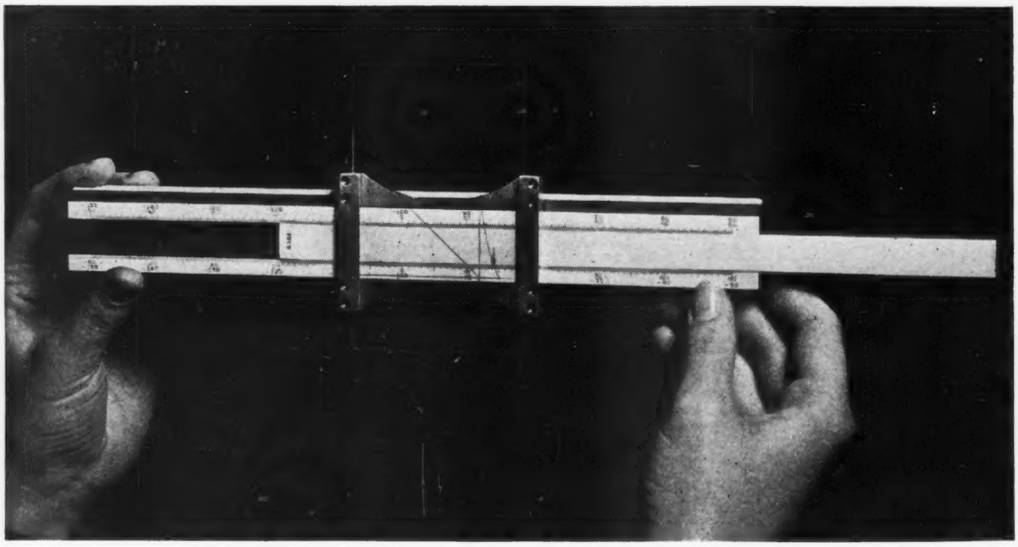


Fig. 2—Special slide rule, for combining db levels, which embodies the curve of Figure 1 directly on the indicator. The indicator slides both horizontally and vertically

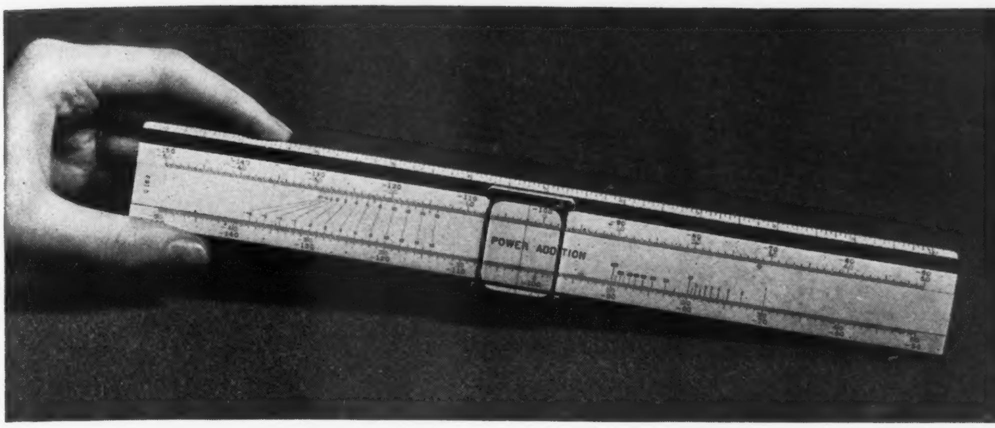


Fig. 3—Slide rule with the increments of Figure 1 shown by broken lines on the slide

many components which are equal in magnitude. As set in Figure 3 a level of 30 db on the lower scale under the index 1 on the slide is the result of the combination of 10 components each of 20 db, or 50 each of 13 db, etc.

A third device for adding the components is shown in the headpiece. It was designed by W. Koenig, Jr., specifically for computations of integrated spectra, each of which involves many components. The operator sets an index on each component in turn. The cumulative "sum" is available at all times. This device is based on the same principle as the others and is illustrated in Figure 4, with the cover removed. Two index lines are inscribed on a transparent disc of lucite; the outer is a circle and the inner a spiral. As seen through the window of the cover, the spiral looks like a slightly curved line which moves along the scale when the disc is rotated. By offsetting the center of the spiral from the scale, the spiral always intersects the scale at right angles, which makes it much easier to set accurately. The answer is read from the scale beneath the index line at the extreme right.

Pulling the thumb lever at the left actuates a friction clutch, which grasps the slide and moves it to the left until a small point on the arm above the slide strikes the edge of the disc. This edge is shaped to correspond to the curve of Figure 1. Releasing the thumb lever first releases the clutch, then allows the arm to resume its normal position against an adjustable back stop. The travel of the arm is 3 db along the scale when the spiral intersects the circle, which corresponds to adding two equal components. At the point of maximum separation between the circle and the spiral, which corresponds to about 18 db difference in level between two components, the arm almost touches the edge of the disc and consequently permits only a very small advance.

In using this device only that part of the lucite disc at the right of the shaft in Figure 4 is visible to the operator, as shown in the headpiece. The first component is set under the index line at the right by moving the slide through the apparatus by hand. The second, and each subsequent component, is set by turning the lucite disc which moves the left index line to the desired position on the scale. Operating the thumb lever to the limit of its motion after each set-

ting automatically moves the slide by the appropriate increment. The progressive "sum" then appears under the index line at the operator's right. Operation is simplest when the largest component of the series is set first but thereafter they may be taken in any order that is desired.

These models all have approximately the same accuracy—about 0.1 db. Components so far below the cumulative sum that individually they do not add an appreciable increment are neglected. If there is a large number of these, the accuracy will be improved by totalling the low components separately and adding this sub-total to the sub-total of the high components.

These devices have been in use for about two years and have proved eminently practical. They are known by those who use them as "db adders." The particular scales shown in illustrating the several devices are those which apply when the components combine on a power basis. Similar scales can be provided for other laws such as those encountered with the addition of current or voltage.

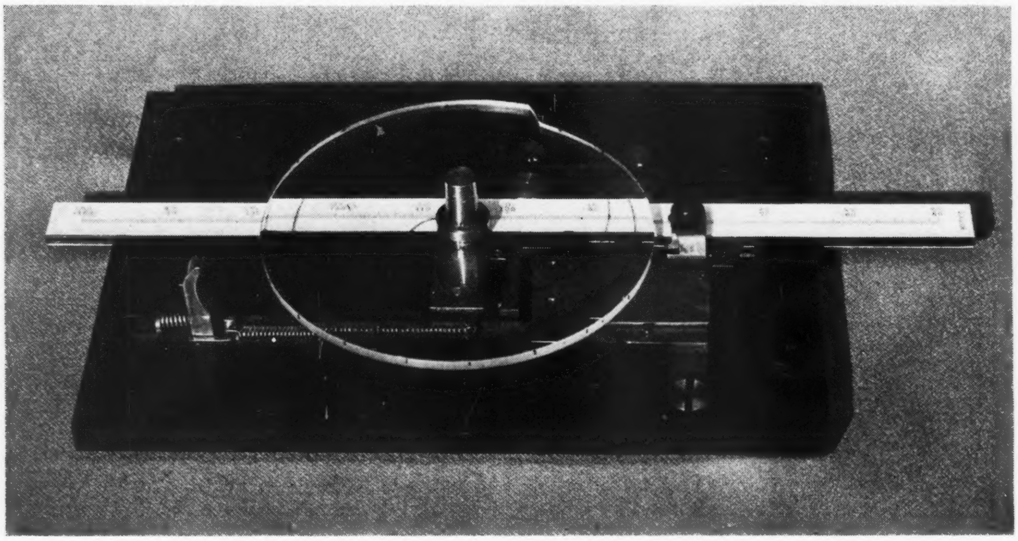


Fig. 4—Mechanized arrangement for adding db increments. The disc is shaped to conform to Figure 1 and acts as a stop to the clutch which advances the slide

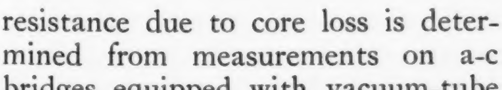
Analysis of Losses in Magnetic Cores

By C. D. OWENS
Transmission Apparatus Development

When a ferromagnetic core is introduced into the field of a coil to increase its inductance, it exacts a compensation in energy for its contribution. This toll, which is dissipated in the magnetic material, is called core loss. The core of a transformer in a power-transmission system, for example, may become hot to the touch, providing tangible evidence of the dissipation of energy. In fact a measurement of the heat developed in such a core can be used to determine the magnitude of the core loss, commonly expressed in watts per unit weight of the core material. In the design of power apparatus, the core loss must be limited to prevent excessive waste of energy in overheating.

In a high-quality inductance, such as a loading coil or network coil used in communication circuits, where the energy levels are relatively very low, the power dissipation due to core loss is negligible so far as heating is concerned. The effects of core loss on the performance of these coils in transmission circuits are of such importance, however, that they govern the practical application of ferromagnetic core materials. The measurement and analysis of core loss consequently assume fundamental rôles in the development of ferromagnetic materials and the design of high-quality coils employing them.

Instead of a direct measurement of the heat developed in the core of a high-quality coil, the increase in series resistance due to core loss is determined from measurements on a-c bridges equipped with vacuum-tube amplifiers. The procedure is to measure the effective resistance R_e and subtract from it the winding resistance. The difference is the core loss resistance ΔR. The winding resistance consists of the direct-current resistance R_{dc} plus an alternating-current resistance R_x arising from eddy currents, dielectric loss, and distributed capacity in the winding. This latter resistance can be determined from measurements on the winding without the magnetic core. Figure 1 illustrates schematically these various resistances in series with the inductance.



$$\text{FIGURE OF MERIT, } Q = \frac{\text{REACTANCE}}{\text{EFFECTIVE RESISTANCE}} = \frac{2\pi f L}{R_{dc} + \Delta R + R_x}$$

Fig. 1—Core loss appears as one of the components of the effective resistance of a coil that has a magnetic core

The ratio of the inductive reactance to the effective resistance is commonly employed as a quality factor or figure of merit of the coil, termed "Q." To yield the highest value of "Q" for a given inductance, the core loss and winding resistance must be made as small as possible. A net gain in "Q" is realized from the use of a ferromagnetic core in place of a nonmagnetic core when the reduction in winding resistance due to the smaller

number of turns required is greater than the resistance added by core loss.

Core loss, or the amount of energy dissipated, increases with both frequency and the magnitude of the induced flux. Hence, in a communication circuit, which has as its function the faithful transmission of a current of complex wave form, the core loss in the magnetic material acts to modify the shape of the transmitted wave and reduce the fidelity. Its effects are to attenuate the higher frequencies more than the lower and to introduce nonlinear distortion. Since transmission requirements on most network and loading coils are severe in these respects, it is helpful not only to determine the total core loss, but to divide it into frequency and current components which can be related to the operating characteristics of the coils.

Investigation has shown that the total increase in resistance due to core loss may be divided into three components: one proportional to the square of the frequency, one to the product of frequency and the maximum flux density, and one to the first power of the frequency. The first of these components is called the eddy-current-loss resistance, the second the hysteresis-loss resistance, and the third the "residual"-loss resistance. An equation expressing them would be written:

$$\Delta R = e\mu f^2 L + a\mu B_m f L + c\mu f L \qquad (1)$$

Dividing through by $\mu f L$, this equation becomes

$$\Delta R / \mu f L = ef + aB_m + c.$$

In these equations e, a, and c are eddy current, hysteresis, and "residual" coefficients of the core material respectively, μ is the effective permeability of the core, f is the frequency, B_m the maximum flux density in the core, and L the inductance of the coil.

The coefficients e, a, and c may be evaluated by determining ΔR from a-c bridge measurements at two or more frequencies at constant current, and two or more currents at constant frequency, and solving the set of equations simultaneously. In practice this solution is obtained graphically as illustrated in Figures 2a and 2b. When values of $\Delta R / \mu f L$ are plotted for the same value of current (or flux density) at two or more frequencies, a straight line may be drawn through the points as shown in Figure 2a. The slope of this line is "e," and the ordinate intercept is $c + aB_m$. Similarly when points are plotted for different flux densities but at the same frequency, the line shown in Figure 2b is obtained. The slope of this line is

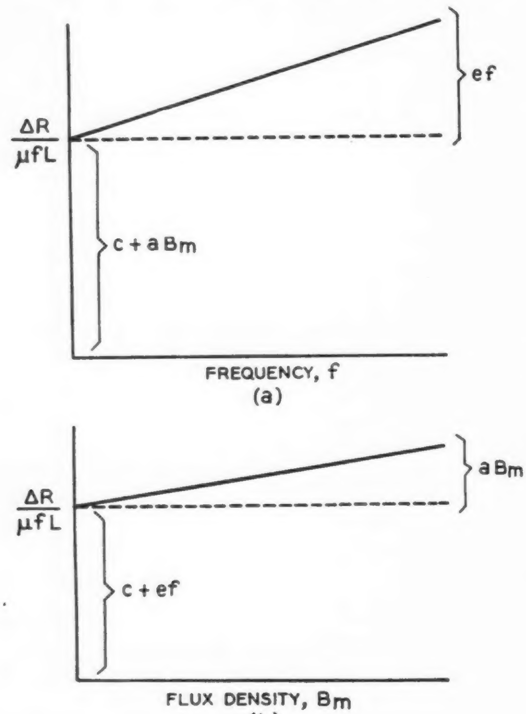


Fig. 2—With constant current, upper graph, the relationship between $\Delta R / \mu f L$ and frequency is a straight line; and for constant frequency, lower graph, the relationship between $\Delta R / \mu f L$ and flux density is also a straight line for small values of flux density

"a," and the ordinate intercept is $c+ef$. This determines both "e" and "a," and by substituting these values into the expressions for the ordinate intercepts, "c" is obtained.

Once these coefficients are known for a given core structure, the core-loss resistance can be calculated for other currents and frequencies and for other inductances by substituting in Equation 1. Furthermore, a knowledge of the relationship of these coefficients to the physical properties of the core material and to the electrical behavior of the coil is very helpful in developing improved core materials and in guiding their application.

The eddy-current coefficient "e" is an index to the energy dissipation arising from currents induced in the magnetic core material by variations in the current through the coil winding. The eddy currents flow in planes perpendicular to the paths of magnetic flux, and have magnitudes which depend on the value and rate of variation of the magnetic flux and on the resistance of the conducting paths available to the currents. This resistance is proportional to the resistivity of the magnetic material and the constriction of such paths. If the core is laminated parallel to the paths of the magnetic flux the eddy current losses can be shown to be proportional to the square of the lamination thickness. If the core material is subdivided into small particles insulated from each other, the eddy current losses are proportional to the square of the particle diameters. In high-quality coils such as filter or network coils, core rings made of insulated and compressed magnetic powder are commonly used because the eddy currents are minimized by the extremely fine size of the particles. Overall losses are limited by controlling the effective permeability through proper adjustment of the ratio of insulating and magnetic materials. The determination of "e" can be used in connection with the development and manufacture of such cores to indicate the uniformity of the various processes, such as grinding or the application of

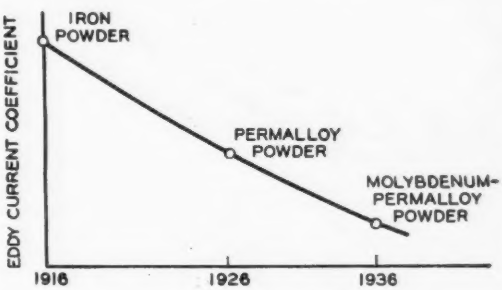


Fig. 3—Improvement in eddy current coefficient in cores used for voice-frequency loading and retardation coils over the last twenty-four years

the insulation, or to indicate the effects of systematically controlled changes in these processes.

The hysteresis-loss coefficient "a" depends upon the composition of the material and the heat treatment. Its magnitude is controlled therefore by selecting the most suitable material and employing the most favorable processing. The hysteresis loss is important not only because of its contribution to the effective resistance of the coil, but also as a source of distortion of the wave form in the circuits with which it is linked. This distortion arises from harmonics and new frequencies caused by the non-linear relation between the magnetizing force and the resulting magnetic flux. These new frequencies may cause not only distortion in the circuit containing the magnetic material, but may produce disturbances in adjoining channels of multi-channel circuits. It has been shown that these effects are propor-

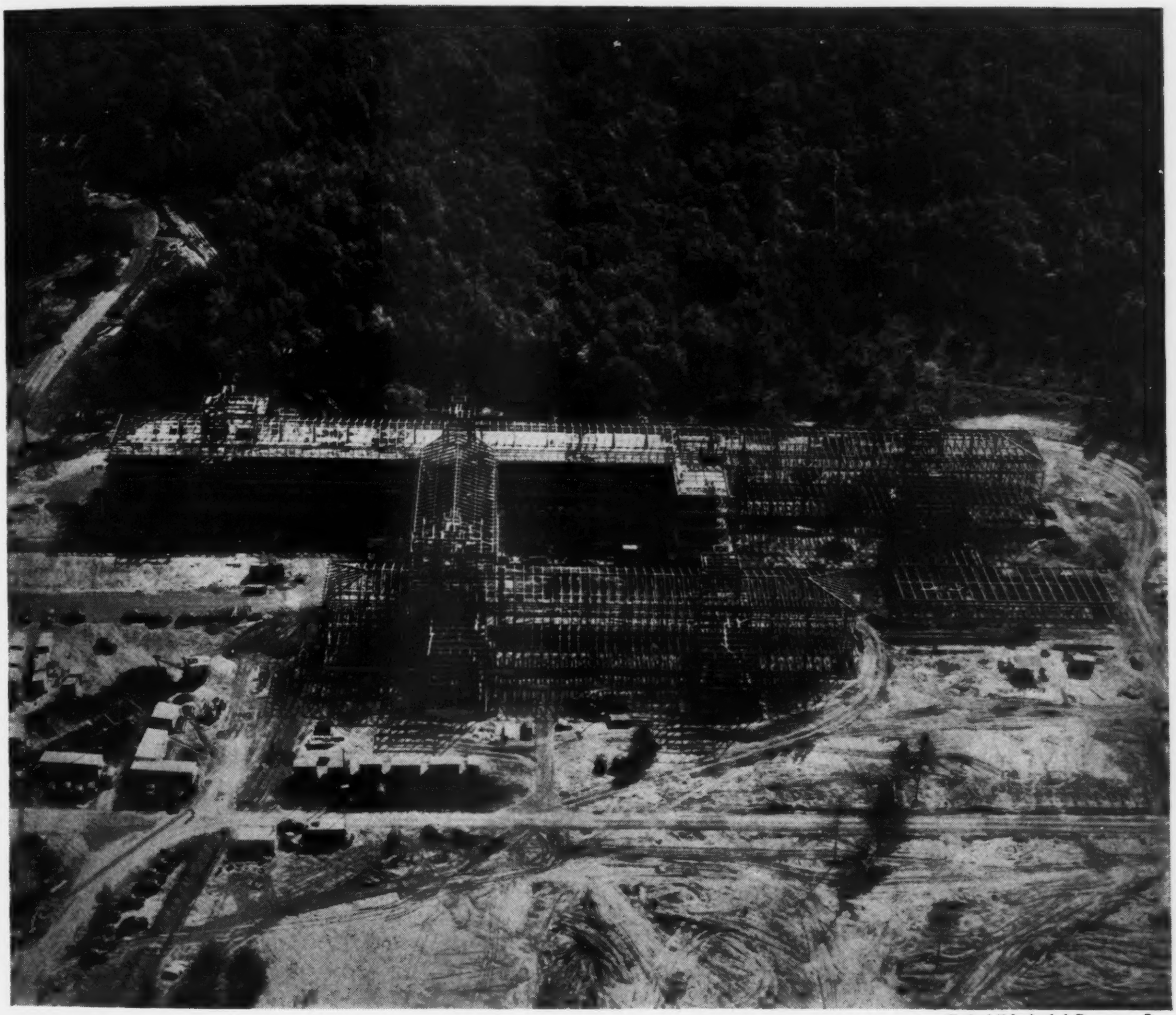
tional to the product $a\mu B_m$. The harmonic distortion, or modulation, is thus conveniently related to an intrinsic property of the magnetic material, and the relatively simple determination of the hysteresis coefficient "a" may be used in place of more involved modulation measurements for predicting and controlling this effect of the magnetic core. As in the case of the eddy current coefficient "e," a study of the change in the hysteresis coefficient "a" with variations in manufacturing processes may be used to determine directions for improvement of the core material.

The "residual" loss term in Equation 1 is a result of the observation that the total core loss as accurately measured on a-c bridges is larger than can be accounted for by the two eddy current and hysteresis components as conventionally determined. This additional component has been referred to also as "initial hysteresis" and "magnetic viscosity." Since the increase in resistance of a coil due to "residual" loss is a function of only the first power of the frequency, is independent of flux density, and does not contribute to harmonic distortion, it is not of as much consequence as the eddy current and hysteresis losses. Nevertheless it is desirable to keep the residual constant "c" as low as practicable. The physical basis of residual loss is still a matter of conjecture, but some control of the coefficient "c" is obtained through proper choice of composition and heat treatment of the material.

The utility of core loss determinations in development work and manufacturing control depends also upon means available for rapid and accurate measurements. As the quality of the core is improved, the ratio of core loss to the total effective resistance measured on the bridge decreases, requiring greater precision of measurement. Figure 3 presents, for example, a picture of improvements in the eddy current losses in cores used in voice-frequency loading and network coils during the past several years. To provide high speed and accuracy for the measurement of present-day materials, a new bridge has recently been designed and built and described in a previous article.* In the best quality cores, where highest accuracies are required, the test coils are prepared with a special standardized winding designed to minimize the a-c winding losses. The coils are thoroughly dried and then placed in hermetically sealed containers for measurement. The measuring equipment is maintained in air-conditioned rooms under practically constant conditions of temperature and humidity. Both alternating and direct-current measurements are made on the same circuit to avoid changing connections or handling the coils.

*RECORD, *November*, 1940, *p.* 92.

NEWS AND PICTURES OF THE MONTH



Fairchild Aerial Surveys, Inc.

This view of the new Bell Telephone Laboratories' building at Murray Hill, New Jersey, shows the general outline of the structure as it appeared on October 16. The main entrance will be reached through the forecourt at the left in the structure connecting the rear laboratory building with the chemical laboratories in the foreground. The one-story structure at the right will contain the restaurant and cafeteria; directly above these and connecting with the main building will be the clubrooms. The acoustical laboratory and auditorium are not shown in this view but will be located slightly in front and to the right of the restaurant. The heating plant is shown in the upper left-hand corner where also will be located a garage and electric substation.

News of the Month

Anniversary of Transatlantic Radio Telephone Service

The twenty-fifth anniversary of the first successful transmission of speech across the Atlantic by radio telephone was celebrated on October 21, 1940, when engineers who accomplished the feat gathered at the Laboratories. Since war conditions prevented the reënactment of the original talk to Paris, another of those early tests was echoed by a telephone call from Dr. Jewett to A. A. Scott, President of the Mutual Telephone Company at Honolulu.

The radio telephone tests in which this group of Bell System engineers participated twenty-five years ago were a forerunner of the transoceanic radio telephone service of today, by which any telephone in the United States can be connected to practically any other telephone anywhere else in the world, war conditions permitting. The transmitter of twenty-five years ago was located at the Arlington Radio Station where an antenna was made available through the coöperation of the United States Navy. It was manned by R. A. Heising, B. B. Webb and H. W. Everitt. The listeners in Paris, H. E. Shreeve and A. M. Curtis, had the use, at intervals, of a radio antenna on the Eiffel Tower through permission of the French Government. At the same time Lloyd Espenschied was stationed at the Naval Base at Pearl Harbor, Hawaii; R. V. L. Hartley was at San Francisco; William Wilson at San Diego; and R. H. Wilson at Panama. O. E. Buckley and H. Weinhart were concerned with the production of vacuum tubes. B. W. Kendall and C. R. Englund, after working on apparatus design, monitored the transmitter output at a receiver in New York. John Mills was transmission engineer for the

Reunited at the Twenty-fifth Anniversary of Transatlantic Radio Telephony were: (Standing) R. A. Heising, W. Wilson, O. E. Buckley, A. M. Curtis, B. W. Kendall, R. H. Wilson, H. Weinhart, R. V. L. Hartley, C. R. Englund and H. W. Everitt; (Seated) F. B. Jewett, H. E. Shreeve, B. B. Webb, L. Espenschied and E. H. Colpitts

Seldom does a physician receive the tribute of affection and gratitude which came to Dr. John Slater Waterman at a dinner tended to him on October 23 on the occasion of his retirement. The camera caught Dr. Waterman in the midst of this group of his friends

project. Speech transmitted from Arlington was heard by all of these observers at various times between August 26, 1915, and October 21; at Paris, which was the principal objective to be reached in the tests, the signals received on October 21 were good enough so that the French officers listening could state that transoceanic radio telephony had been accomplished.

Success of the tests was due to careful planning and preparation. The project was in general charge of Dr. Jewett and E. H. Colpitts. Those present paid tribute to the late General John J. Carty whose imagination and foresight were responsible for the initiation of the project, and to the contributions of the late Dr. H. D. Arnold, who was in direct charge of the research phases of the subject.

After the completion of the Arlington tests, the transmitter was dismantled and the observers came home. The tests had emphasized the need for larger tubes so as to reduce to a workable number the 550 tubes of 20 watts each in the final stage. Military needs preoccupied the Laboratories for a time, but in 1921 the invention of the copper-to-glass seal made possible a 10,000-watt tube. In the following year, work on transatlantic telephony was renewed, using the Radio Corporation's large antenna at Rocky Point, Long Island. Profit was taken of the work which had meanwhile been done on radio and carrier systems, and on January 15, 1923, a public demonstration was made of transmission from New York to London. So successful was this that the British Post Office erected corresponding equipment. Problems of interconnection of telephone lines with radio were successfully solved, and on January 7, 1927, transatlantic service was opened for public use.

The Telephone Business

Reductions in telephone toll rates from points in New York City and vicinity to certain points in Northern New Jersey comprising roughly the suburban area have been announced by the New York Telephone Company and the New Jersey Bell Telephone Company.

Effective December first, the new rates are a reduction of five cents from previous rates. For example, on calls from Manhattan south of 57th Street:

Locality	*New Rate*	*Old Rate*
Morsemere	10¢	15¢
Elizabeth	15¢	20¢
Montclair	15¢	20¢
Orange	15¢	20¢
Paterson	15¢	20¢
Perth Amboy	20¢	25¢
Rahway	20¢	25¢
Summit	20¢	25¢
Morristown	25¢	30¢
Plainfield	25¢	30¢
Dover	30¢	35¢

A new telephone numbering plan for southern Westchester will become effective with the issue of new telephone directories

next June. Digits will be added to the names of certain offices, while the names of other offices will be changed. In addition, a few subscribers' line numbers will be changed. The new arrangement is in preparation for dial cut-overs, the first of which will be in Mount Vernon in March, 1942, affecting Hillcrest and Beverly telephones. Others will follow in Yonkers and New Rochelle. The entire program for southern Westchester will take a number of years to complete.

Members of the Laboratories in the area affected will receive from the New York Telephone Company a booklet describing the changes so that they may be in position to answer questions from their neighbors about the reasons for the change in central office designations.

Stevens Point-Minneapolis Coaxial System Meets an Emergency

From November 11 to 12 an early winter storm of unusual severity, marked by tornadoes, blizzards, and near-zero temperatures, swept across the country from the Rocky Mountains to the Appalachians doing heavy damage to property over a wide area. In some sections open-wire telephone lines were hit hard. In the upper Mississippi Valley the Madison-La Crosse-Hastings and Davenport-Minneapolis routes suffered numerous wire breaks.

In this emergency the new type-L carrier system, on which installation and testing is in progress between Minneapolis and Stevens Point, was rushed into service, despite the fact that regular commercial service is not scheduled to begin until the middle of next year. Fifteen Chicago-Minneapolis circuits were routed over the coaxial between November 11 and November 15. All of the emergency circuits were restored to normal routings as soon as the storm damage was repaired.

J. F. Morrison studies his notes during his lecture on "Transmitters," one of a series in a course on frequency modulation conducted by the Communication Group, A.I.E.E.

Colloquium

K. K. Darrow spoke on *The Ionosphere* at the October 21 meeting of the Colloquium. The ionosphere is a region in the very high atmosphere from which radio signals are reflected, a fact which is adequately explained by assuming that region to be populated with free electrons. In exploring the ionosphere, signals of a wide range of frequencies are successively sent upward, and the time elapsing before the return of the echo is measured. The delay of the echo multiplied by one-half the velocity of the waves is called the virtual height of the ceiling for the signal. Curves are then plotted relating virtual height of ceiling to frequency of signal. These curves are peculiar in shape and vary remarkably with time of day, time of year and epoch of the solar cycle. By theory they can be translated into curves relating electron-density to true height above ground. The theory is approximative, but the results are accurate enough to be of value. The magnetic field of the earth affects the observed values remarkably, making it possible to test the theory and to evaluate the field-strength at great heights. The free electrons are supposed to be liberated from the air-molecules by ionizing agents, of which the chief but not the only one is ultra-violet light from the sun.

At the November 4 meeting, G. R. Stibitz lectured on *Calculating With Telephone Equipment*. For years telephone relays have benefited from numerical calculations per-

formed by telephone engineers, and the time has come to return the favor. Telephone engineers are now benefiting from numerical calculations performed by telephone relays. A calculator composed entirely of relays and similar telephone and teletypewriter equipment has been constructed to carry out the tedious computations with complex numbers which are needed in the design of transmission networks.

The Colloquium has received a number of inquiries regarding the requirements for membership. Any member of the Laboratories is qualified if he either has published original research in a recognized scientific journal or is a member of at least one of the following societies: the American Chemical Society, the American Mathematical Society, or a member society of the American Institute of Physics. Anyone in the Laboratories who is qualified to become a member of the Colloquium may obtain an application blank from Miss Kilpatrick on Extension 484.

DR. MELVILLE H. MANSON
recently appointed Medical Director of the Laboratories

NEW MEDICAL DIRECTOR OF THE LABORATORIES

MELVILLE H. MANSON, M.D., who became Medical Director of the Laboratories upon the retirement of Dr. J. S. Waterman, is a graduate of the University of Minnesota where he received his B.S. degree in 1926, B.M. in 1928, M.D. in 1929, M.S. (Surgery) in 1932 and Ph.D. (Surgery) in 1934. Following graduation from Medical School, Dr. Manson served a year's rotating interneship at the University of Wisconsin General Hospitals. From 1930 to 1933 he was a teaching fellow in surgery at the University of Minnesota Hospitals and from 1934 to 1937 served as an instructor in surgery in these hospitals.

Early in 1937 he became a special representative with the American College of Surgeons in which capacity he engaged in making a survey of the surgical training facilities in the United States. Upon the completion of this work later that year he accepted a position with the Commonwealth Fund as a medical executive in the hospital division. He served in an advisory capacity on matters pertaining to the establishment of hospital facilities in communities.

Dr. Manson is a member of Sigma Xi, Alpha Omega Alpha, American Society for Cancer Research and a fellow of the American College of Surgeons. He has written a number of papers that have been published in scientific and medical journals.

NEWS NOTES

THE MENDHAM property of the Laboratories, used for a number of years by the Radio Development Department, is now on the market for sale. The property has been divided into three parcels: 25 acres, 49 acres and 58 acres. The 49-acre parcel which includes a dwelling and garage has already been sold. The larger of the two remaining parcels includes an old frame house and the laboratory building erected since the acquisition of the property.

F. B. JEWETT, as president of the National Academy of Sciences, presided over the autumn convention of the Academy, held from October 28 to 30 in Philadelphia, and spoke briefly at the dinner held on October 29. O. E. Buckley, Harvey Fletcher and H. E. Ives attended various meetings during the convention.

DR. BUCKLEY has been appointed a member of the committee on the John J. Carty Fund of the National Academy of Sciences, to serve until April, 1946.

H. S. SHEPPARD, at a Patent Department luncheon held on October 30, spoke on *The License Contract.* B. F. Stoddard made the arrangements for the luncheon.

LEAVES OF ABSENCE to enter military

service have been granted to H. W. Schaefer, 165th Infantry, Fort McClelland, Anniston, Alabama; W. K. St. Clair, Corps Area Signal Office, Governors Island, New York; D. L. Viemeister, United States Naval Reserve Radio School, Noroton, Connecticut; and J. R. Sackman, Bureau of Ships, United States Navy, Washington, D. C.

M. E. STRIEBY, High Frequency Engineer of the Transmission Development Department, has been appointed Transmission Engineer of the Long Lines Department, American Telephone and Telegraph Company. Since his transfer to the Laboratories in 1929 from the Department of Development and Research of the American Telephone and Telegraph Company, Mr. Strieby has been in charge of coaxial systems development and has contributed largely to its success.

J. F. WENTZ, in charge of line engineering and measurements under Mr. Strieby, succeeds him. Mr. Wentz was graduated by Lehigh University in 1917 and entered the Laboratories in 1919. His principal contributions have been in the fields of loaded submarine cables and more recently of coaxial cables, particularly in the study of transmission characteristics and the development of methods of measurement.

ON OCTOBER 11, Harvey Fletcher, J. C. Steinberg and W. B. Snow visited the Clarke School at Northampton, Massachusetts, to inspect the present teaching methods using group hearing aids.

AN ARTICLE ENTITLED *Testing America's Ears*, by F. L. Hunt, was published in the October issue of the *Bell System Quarterly*. Records of more than half a million individual tests at the Bell System Exhibits of the New York and San Francisco World's Fairs have provided the most extensive data ever compiled for the study of hearing.

D. R. MCCORMACK discussed and demonstrated *Centralized Transcribing by Telephone* before a conference of the American Management Association held in New York City on October 25.

* * * * *

G. C. CRAWFORD of the Systems Development Department retired from active service on the thirtieth of November, having completed over thirty-two years of service in the Engineering Department of the Western Electric Company and the Laboratories. Mr. Crawford received the A.B. degree from Harvard University in 1902 and the degrees of A.M. and S.B. in Electrical Engineering in 1903 and 1904. In 1905, after a year teaching physics at the University of North Carolina, he joined the Engineering Department of the Western Electric Company.

At the fall meeting of the Edward J. Hall Chapter, Telephone Pioneers, held at the Hotel Commodore on November 7. Left, and then around the table clockwise: O. B. Blackwell, Mrs. A. F. Dixon, O. E. Buckley, Mrs. Blackwell, William Wilson, H. Wilson (a guest), A. B. Clark, Mrs. Clark, A. F. Dixon, and Mrs. Buckley

About this time Mr. Crawford became associated with E. C. Molina in a study of the application of probability to trunking problems. In the course of this study Mr. Molina submitted, for computation and reduction to curve form, a formula for the approximate evaluation of the incomplete binomial expansion which involved certain parameters n and p. Mr. Crawford, in supervising this computation, observed that as p became small and, simul-

taneously, n became large, it was not necessary to know the values of both in order to evaluate the binomial summation; it sufficed to know only the value of the product of n and p. This important fact was called to the attention of Mr. Molina with the result that in 1908 he introduced into the solution of trunking problems his Poisson trunking formula.

In 1908 Mr. Crawford left to instruct in physics at the College of the City of New York, but in 1911 he returned to West Street to engage in the development of ringing systems, particularly the harmonic selective ringing system. When the wartime engineering work was undertaken he took part in the development of circuits and the preparation of bulletins covering the operation and maintenance of radio equipment for airplanes and submarine chasers.

G. C. Crawford

G. W. Burchett

Since 1922 Mr. Crawford has been concerned with the development of repeaters, and during this period was closely associated with all of the work on the 22A1 (two-wire) and 44A1 (four-wire) repeaters. Mr. Crawford has also been connected with the development of program circuits for broadcasting systems since the beginning of this work, particularly the 12-type and 14-type amplifiers used in these circuits. Beginning in 1928 he was associated with the development of transmission measuring and control circuits, such as the 1A amplifier-rectifier that is used in the No. 8 test board and the more recently developed 40B transmission-measuring system.

For the three years previous to his retirement the development of testing and maintenance switching methods for carrier and coaxial repeaters was also included in his work. He has rounded out his career by supervising the development of a new telephone repeater, the V-1, which is the most substantial design improvement in voice-frequency repeaters since the vacuum-tube repeater was introduced into the telephone plant over twenty years ago.

With over twenty-nine years of service to his credit, G. W. Burchett of the Physical Research Department retired on November 30. Before Mr. Burchett came to the Bell System he spent several years in the organizations of Hudson Maxim and Thomas A. Edison. He joined the Special Apparatus Department of the Western Electric manufacturing organization in 1911 and when this was moved to Hawthorne he transferred to the Model Shop. There he developed special automatic machines for the manufacture of vacuum tube grids. During the war he joined the printing telegraph group where he assisted in the design and development of various types of printing machines.

In 1921, Mr. Burchett entered one of the Laboratories of the Physical Research Department as an expert mechanic. One of his first jobs was the development of the 540AW loud-speaking telephone on which he received a patent. Since then he has been associated with the development of special equipment and apparatus that is used by the Physical Research group. He has also been granted several patents for his work on the artificial larynx.

* * * * *

W. A. Menhmel of the Finishing Shop of the Plant Department is the man shown in the Frontispiece on page 105.

K. K. Darrow spoke on October 17 befor the Physics Colloquium of M.I.T. on *Helium the Superfluid;* on October 19 before the New England section of the Physical

In the Plant Shops

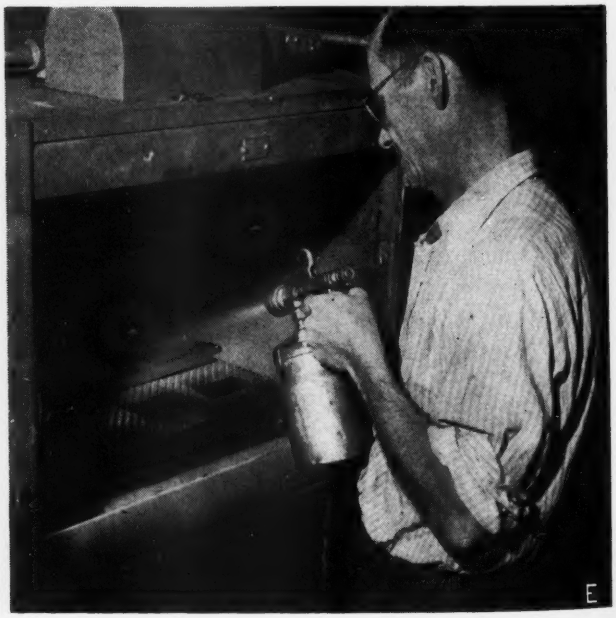
A—*M. V. Hickey discusses details of a carpenter shop order with F. Schuler*

B—*In the Cabinet Shop, Herman Garlisch operates a jointer*

C—*The stockroom which supplies materials to the Building Shops is in charge of R. J. Hluboky*

D—*H. A. Kohler, a junior mechanic, cleaning parts in the Finishing Shop as part of his training in the Development Shop*

E—*T. E. Cassidy sprays a telephone apparatus panel in the Finishing Shop*



Society on *The Principle of Indefiniteness;* and on October 25 before Sigma Xi at Smith College, Northampton, Massachusetts, on *The Fission of Uranium.*

R. M. Bozorth, on November 6, discussed *The Physical Basis of Ferromagnetism* before a science group of the Pittsfield plant of the General Electric Company.

F. S. Goucher, assisted by J. R. Haynes, presented his lecture-demonstration, *The Microphone and Research,* before the Science Forum of the New York Electrical Society on October 17. He also presented the same talk before the Patent Society in Washington on November 7.

A conference on *Nuclear Physics* held at the Massachusetts Institute of Technology was attended by K. K. Darrow, W. Shockley, F. C. Nix and H. G. Wehe. A paper entitled *Neutron Studies of Order in Iron-Nickel Alloys* by F. C. Nix and H. G. Beyer and J. R. Dunning of Columbia University was presented by Dr. Nix.

The Metal Congress and technical sessions of the American Society for Metals and the American Institute of Mining and Metallurgical Engineers at Cleveland were attended by E. E. Schumacher, W. C. Ellis and E. S. Greiner. Mr. Ellis and Mr. Greiner presented a paper entitled *Equilibrium Relations in the Solid State of the Iron-Cobalt System.* The Metals Show, held in conjunction with these meetings, was attended by J. R. Townsend and C. H. Greenall.

A. R. Kemp and F. S. Malm visited the Packard Electric Division of General Motors Corporation at Warren, Ohio, to discuss insulated wire problems. They also discussed the same subject and various rubber problems with engineers of the Western Electric Company at Hawthorne.

H. W. Hermance and T. F. Egan visited Pittsburgh, Washington and Baltimore to carry out field analytical studies in connection with investigation of contact performance in panel equipment.

W. A. Yager, co-author with C. J. Frosch, presented a paper entitled *The Dielectric Behavior of Some Polyesters* at the annual meeting of the Conference on Insulation of the National Research Council. The Conference met in Washington on October 31 and November 1 and 2. G. T. Kohman, D. A. McLean, E. J. Murphy, H. A. Sauer, M. D. Rigterink and S. O. Morgan also attended this conference.

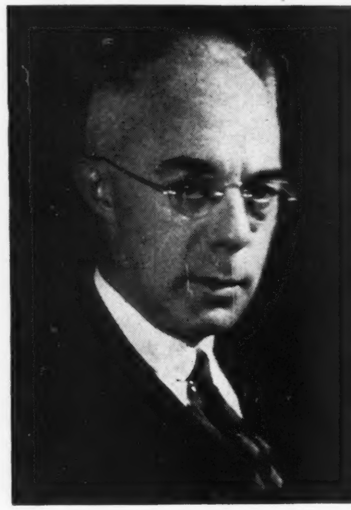
R. M. Burns and H. E. Haring attended a meeting of the Electrochemical Society held in Ottawa.

In a half-column article in the Boston *Transcript* for October 28, R. M. Foster discussed the probabilities of the order in which numbers of the recent Selective Service draft would be drawn.

H. A. Birdsall attended a convention of the American Association of Textile Chemists and Colorists that was held in New York City on the eighteenth of October.

P. H. McKeel of the Radio Development Section, Civil Aeronautics Authority, inspects an Azimuth Indicating Radio Receiver that has since been installed at La Guardia Field. H. B. Fischer is on the right

AMONG THE EDUCATIONAL organizations that have undertaken programs of participation in the defense program, the activities of the mathematicians have especial significance in that the applications of mathematics are of basic importance both in constructing and in operating the machines used in present-day mechanized warfare. T. C. Fry has been appointed a consultant to a joint committee of the American Mathematical Society and the Mathematical Association of America which will carry on education and research in those aspects of mathematics that aid in preparation for war.



L. B. EAMES

R. S. DECKER received an Honors Award at Newark College of Engineering for being among the first four in scholastic rating in his class.

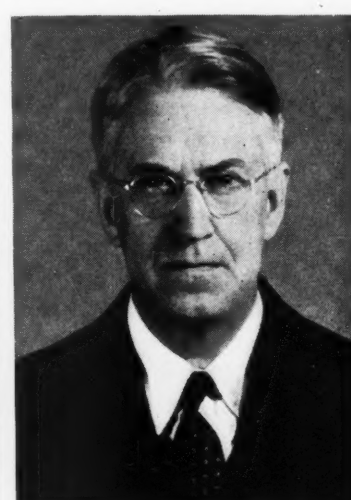
* * * * *

L. B. EAMES completed twenty-five years of service on November 29. He joined the Building and Maintenance Department of the Western Electric Company in 1915 as a stock clerk. Two and a half years later he transferred to the Purchasing Department as a buyer of hardware. Early in 1918 he entered military service and for slightly over a year was in France with the 2nd Pioneer Infantry.

After the war Mr. Eames returned to the Purchasing Department. In 1921 he went to the Apparatus Development Department as a service clerk and a few years later became supervisor in charge of all types of services for engineers. When the Outside Plant Development Department came to West Street from the Maltz building, services for this Department were transferred to Mr. Eames' group. His responsibilities cover the coördination of relations of the engineers with the Purchasing Department and the Western Electric order-service department and includes obtaining materials from stockrooms, furnishing porter service, issuing orders on the various development and plant shops, and the shipment of apparatus and equipment. In 1939 when service groups were reorganized and certain of their functions trans-

PHILIP CURRAN
of the Plant Department completed thirty years of service in the Bell System on the second of November

W. J. CUDDY
of the General Accounting Department completed forty years of service in the Bell System on November 2



J. C. FIELD
of the Switching Apparatus Development Department completed thirty-five years of service on November 6

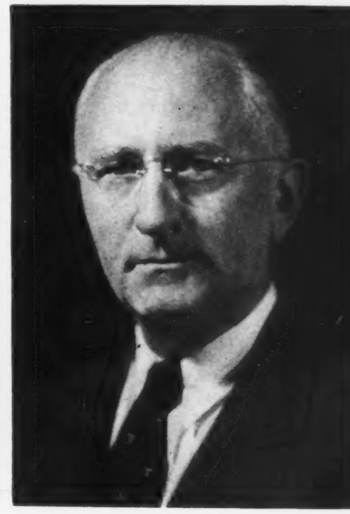
ferred to the General Service Department, Mr. Eames continued his responsibilities in the local service group of this Department.

* * *

A. M. SKELLETT spoke before the Metropolitan Section of the American Physical Society on the subject *The Coronaviser.* This meeting of the Metropolitan section was held in the Columbia Broadcasting Studios in New York City on November 15.

PRIOR TO THE OPENING of a new coastal-harbor radio telephone station, H. B. Coxhead spent some time at Tampa, Florida, and its vicinity making tests and studying requirements of this type of service. Regular telephone service through the Tampa station was begun on November 1.

L. B. STARK
of the Switching Development Department completed thirty-five years of service in the Bell System on November 13



J. M. FINCH
of the Chemical Laboratories completed thirty years of service in the Bell System on November 28

A PAPER PREPARED by W. R. Goehner on *A New Mirror Light Modulator* was presented at the fall Convention of the Society of Motion Picture Engineers held in Hollywood on October 22.

DURING THE MONTH of November the following members of the Laboratories completed twenty years of service in the Bell System:

Apparatus Development Department
W. H. Harvey — I. S. Rafuse

Systems Development Department
A. D. Knowlton — Miss M. M. McEntee

General Service Department
Miss May T. Brown — J. W. McCaw

Purchasing Department
G. O. Pedersen

Plant Department
William Wynn

J. F. MORRISON spoke on *Frequency Modulation Transmitters* before the Communication Group of the A.I.E.E. New York section on November 4.

E. S. SAVAGE visited Eau Claire, Wisconsin, to inspect the coaxial cable and repeater stations along the Minneapolis-Stevens Point installation. Later he also visited the main repeater station at Baldwin, Wisconsin.

W. A. BISCHOFF attended a meeting of the Technical Drawing Associates, held in Pittsburgh on October 3 and 4.

S. J. HARAZIM visited the Specialty Products Shop at Kearny to discuss changes in the 19-C oscillator.

E. B. WHEELER and J. H. BOWER attended a committee meeting of the American Standards Association on October 1 and 2 at the National Bureau of Standards in Washington. The meeting was devoted to the revision of the standards specifications for dry batteries.

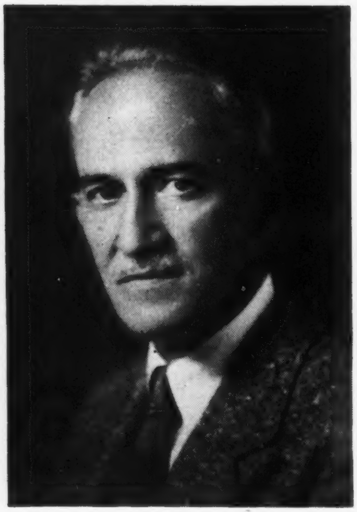
H. H. STAEBNER visited Point Breeze on October 7, and C. A. Webber and R. T. Staples on October 16, to discuss cord development problems.

W. V. THOMPSON discussed problems of the new vacuum tube audiphone cords at Point Breeze on October 25.

H. H. GLENN and E. B. WOOD, at Kearny on October 17, discussed questions in connection with wire development.

AT THE HAWTHORNE plant of the Western Electric Company H. A. Frederick, H. O. Siegmund and J. J. Kuhn discussed relay and switching apparatus problems; T. S. Huxham, the manufacture of molded housings for the combined telephone set; D. H. Gleason, crossbar switches; C. G. McCormick, development of step-by-step banks;

H. T. Pulis, 1888-1940



J. R. Carson, 1886-1940

Mr. McCormick also attended a Quality Survey devoted to this subject; H. W. Heimbach, problems involved in the manufacture of panel apparatus; R. J. Phair, surface finish problems and the standardization of new finish testing equipment; F. W. Treptow, wiring problems connected with automatic ticketing; and C. S. Fuller, enameled wire and molding plastics. Mr. Fuller also presented a lecture before the Western Electric evening school on the subject *Thread-Forming Plastics*.

R. G. Watling visited Albany with L. W. Williams of the A. T. & T. to discuss switching apparatus maintenance questions.

C. Erland Nelson was in Pittsburgh to study panel-bank contacts.

At the General Electric Company in Schenectady, C. H. Greenall, L. N. Hampton and I. V. Williams consulted with engineers on metallurgical problems related to electrically heated soldering coppers.

* * * * *

John R. Carson, research consultant in the Mathematical Research Department, died on October 31 at his home in New Hope, Pennsylvania. Dr. Carson was graduated by Princeton University in 1907, and received a degree in electrical engineering in 1909. After two years with the Westinghouse Electric and Manufacturing Company, he taught at Princeton for two years. In 1914, he entered the American Telephone and Telegraph Company where he took part in the first Bell System radio telephone developments. For a time he was a member of the Patent Department; returning to the Department of Development and Research, he transferred with it to the Laboratories in March, 1934.

One of the outstanding advances in the communications art was Dr. Carson's invention of the single sideband carrier-suppression system of carrier current operation. This system is in use on all long-wave and some short-wave radio circuits, and in wire-carrier circuits of the Bell System and of foreign countries. In recognition the Institute of Radio Engineers awarded him in 1924 the Morris Liebmann Memorial Prize.

While twenty-five patents on specific inventions stand in Dr. Carson's name, his most important work was in the application of mathematical theory to transmission problems, most of which require the use of differential equations. By a happy inspiration, Heaviside had suggested certain simplifications in the arduous process of solving these equations. Dr. Carson proved that the simplifications were sound, and systematized that "operational calculus" so that it has become a useful tool for the network engineer. His book *Electric Circuit Theory and the Operational Calculus* is a classic in this field.

Among the subjects which Dr. Carson studied mathematically was the effect of the current in one wire on the effective impedance of its mate by forcing a non-uniform distribution of the current. He also investigated theoretically the effect of the earth on the impedance of long conductors. He also was active in the theoretical study of wave-guide transmission.

Dr. Carson held the degree of Master of Science from Princeton; he was a member of Phi Beta Kappa, the American Mathematical Society and the Institute of Radio Engineers; and a fellow of the American Institute of Electrical Engineers and of the Royal Society of Arts in London. In 1936, he received the honorary Doctor of Science degree from Brooklyn Polytechnic Insti-

tute; and in 1939 the Elliott Cresson Medal of The Franklin Institute "in consideration of outstanding contributions to the art of electrical communication."

* * * * *

H. T. Pulis, with continuous service with the Western Electric Company and the Laboratories from 1921, died on the twenty-fifth of October. Mr. Pulis had been a group supervisor in the General Service Department. Before joining the Engineering Department of the Western Electric Company he had worked for the Marine Engine and Machine Company in 1904 and 1905, for the New York City Railways from 1905 to 1907 and for the Underwood Typewriter Company from 1907 to 1921. With the Underwood company he became an expert typewriter repairman and came to West Street in this capacity. Mr. Pulis had charge of this work until 1937 when he became supervisor, responsible for mail, messenger, telegraph and typewriter repair services.

* * * * *

John McEvoy, a group supervisor in the General Service Department with over twenty-three years of service in the Western Electric Company and the Laboratories, died on November 3. From 1908 to 1917 Mr. McEvoy worked as a stock clerk for McQuillan and Chase. He then joined the commercial group of the Western Electric Engineering Department as a storekeeper. Early in 1918 he left for military service, serving overseas with the 82nd Division.

After the war Mr. McEvoy returned to his former work and a few years later was placed in charge of general storage at 463 West Street and in outside warehouses. At the close of the war there was a large quantity of apparatus and equipment that had been made for government uses. This was stored in a warehouse on 36th Street. Mr. McEvoy had charge of this and handled all details of its final disposition. In 1928 he was made a supervisor in charge of stores, storage, models, samples, patterns and plant stock.

John McEvoy, 1888-1940

Albert Schreiber, 1894-1940

Albert Schreiber of the Switching Apparatus Development Department, with over twenty-seven years of service in the Bell System, died on November 14. Mr. Schreiber joined the Engineering Department of the Western Electric Company in 1913 and for the next four years, in the Machine Switching Apparatus Department, was concerned with the design and development of various types of machine switching mechanisms and also intimately associated with the development of the panel apparatus installed in the semi-mechanical offices in Newark. From June, 1917, to May, 1919, he served with the 11th U. S. Engineers, most of his time being spent in France.

Upon Mr. Schreiber's return he continued his machine switching development work, but a year later transferred to the Dial Apparatus Laboratory as a test engineer. Previous to his death he had been responsible for setting up and maintaining all test equipment that is employed in this laboratory, including the design of special testing apparatus.

* * * * *

F. J. Redmond visited the Hyattsville office of The Chesapeake and Potomac Telephone Company to inspect crossbar system installations.

C. H. Wheeler and R. B. Bauer were in the Hartford and Glastonbury, Connecticut, offices of The Southern New England Telephone Company to examine line and cut-off relays that are in use in these cities.

V. B. Pike visited The Ohio Bell Telephone Company, Cleveland, and the Illinois Bell Telephone Company, Chicago, in connection with demonstrations of new methods for making temporary water-tight and gas-tight closures for unsheathed portions of lead-covered cables and for cable-end seals.

O. S. Markuson and J. W. Kennard were in New York to discuss carrier cables.

R. J. Nossaman, at Springfield and Boston on October 22 and 23, attended a conference on drop wire and discussed other outside plant matters with members of the New England Company.

A. P. Jahn, with members of the American Society for Testing Materials, inspected the hardware, sheet and wire samples exposed at Brunot Island, Altoona, and State College, Pennsylvania; Sandy Hook, New Jersey; and Bridgeport, Connecticut.

C. S. Gordon consulted with representatives of the Navy Department at Washington on wire problems.

Mr. Gordon served as Chairman of one of the Technical Sessions at the Annual Convention of the Wire Association at Cleveland. At this session, H. Blount and J. E. Wiltrakis of the Western Electric Company presented papers on high-speed wire drawing.

D. D. Haggerty discusses furniture for the new Bell Laboratories Club Lounge with officers of the Club. Left to right: R. M. Burns, E. D. G. Paterson, Mr. Haggerty, R. S. Alford and Miss C. W. Ackerman

Would members of the Laboratories be interested in seeing advance programs of "The Telephone Hour" in the News Notes?

At the Bethlehem office of The Bell Telephone Company of Pennsylvania, T. C. Campbell, L. N. Hampton, H. E. Marting and P. W. Sheatsley, together with Hawthorne and Western Electric Installation Department engineers, inspected the first installation of Western Electric central-office ladders, ladder tracks and brakes.

D. E. Trucksess visited Albany, Cincinnati, Detroit and Chicago to inspect regulated-tube rectifier installations.

V. T. Callahan was in Canton, Ohio, and Lansing, Michigan, on reserve engine design.

J. H. Sole discussed diverter pole generator design in Cleveland.

At Laurelton, New York, H. E. Marting, R. C. Johnson and J. W. Corwin studied crossbar equipment problems.

A. E. Petrie and F. T. Forster were in Philadelphia to discuss storage battery problems. Mr. Forster was also in Washington in connection with similar problems.

H. T. Langabeer visited Gaffney, South Carolina, and Orlando, Florida, to inspect repeater-station power plants that have been rearranged for automatic operation.

C. S. Knowlton was in Philadelphia in connection with the New York-Philadelphia coaxial installation.

W. A. MacMaster recently spent a day at Wilmington, Delaware City and Bayview Beach, Delaware, inspecting the coastal-harbor marine radiotelephone facilities of The Diamond State Telephone Company.

R. E. Hersey and W. I. McCullagh are at Newton, Massachusetts, where they will remain until after the cut-over of the crossbar office now being installed there.

G. A. Hurst and O. H. Williford are now in Detroit in connection with the introduction of crossbar equipment in this area. They will remain in Detroit until after the cut-over.

E. W. Hancock was in Alameda, California, in connection with the introduction of crossbar equipment in this area.

H. N. Christopher and L. Y. Lacy have been at Whippany testing wave-shape corrective filters for rectifiers.

M. T. Dow, R. R. Hough and H. W. Nylund of the Laboratories and L. G. Adam of the Long Lines Department returned from Texas where they had been assisting in noise and crosstalk tests on the Amarillo-Tucumcari cable project. R. P. Booth, H. W. Evans, L. Hochgraf, W. E. Reid, and M. A. Weaver were in Texas at various times during October in connection with this project.

P. W. Spence with J. O'R. Coleman of the Edison Electric Institute attended the annual meeting of the North Carolina section of the American Water Works Association at Raleigh on October 28 and 29. They discussed the results of field investigations of grounding made by the American Research Committee on Grounding.

J. M. Dunham accompanied by T. A. Taylor of the A. T. & T. discussed with engineers of The Bell Telephone Company of Pennsylvania in Philadelphia inductive coordination problems in connection with toll-line dialing.

L. S. Inskip, with T. J. Maitland of the Long Lines Department, were in Eau Claire, Wisconsin, in connection with lightning protection on the Stevens Point-Minneapolis cable. Mr. Inskip also discussed drainage rectifier protection problems with engineers of the Indiana Bell Telephone Company.

H. C. Franke, on a recent trip to Charlotte, studied the transmission stability of type-K carrier circuits.

A. J. Aikens and S. B. Wright spent two weeks in the vicinity of Chicago and Milwaukee in connection with tests on recently installed type-K carrier systems between these two cities. The tests included studies of the possibilities of operating these systems with emergency arrangements which would be required in case of severe damage to a cable or a repeater station. Coöperating

S. S. A. Watkins with false mustache and mandolin contributed to the entertainment of the farewell party at the Bell System Exhibit of the New York World's Fair. Mr. Watkins had charge of the continuous training program required for the Voder operators.

In 1940, 4,796,000 *people visited the Bell System Exhibit out of a total of* 19,603,000 *for the Fair as a whole*

in the tests were G. J. Goetz, G. R. Smith, M. W. Kyser and F. MacMillan of the Long Lines Department in New York as well as Long Lines plant people in the Western area.

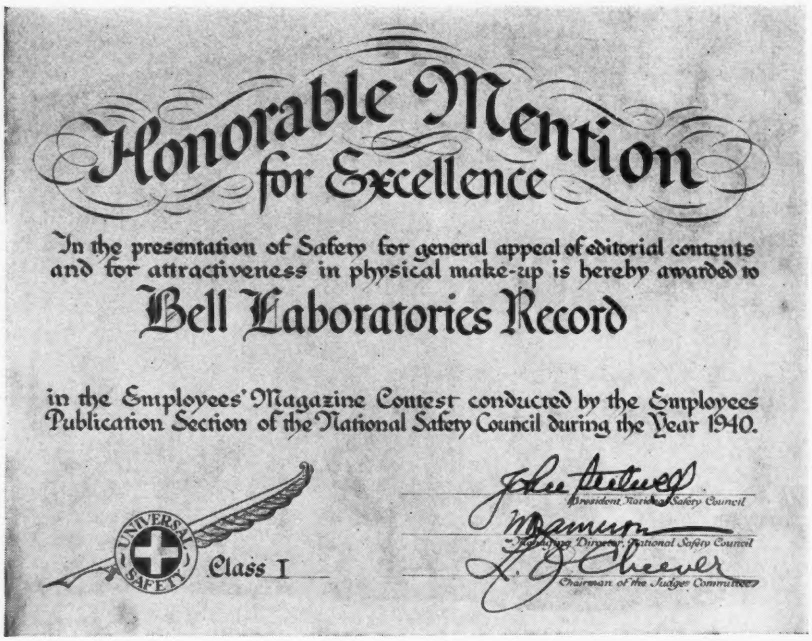
Mr. Aikens also visited the transmission engineer's office of the Wisconsin Telephone Company to render assistance on interference problems.

H. W. Nylund visited Newark and Plainfield to remove experimental installations of 48-volt repeaters which have been on trial at these points.

J. H. Ingmanson and W. G. Straitiff went to Point Breeze on matters pertaining to rubber-covered wire.

E. D. Guernsey took part in an investigation of noise induction in program circuits of the New Jersey Bell Telephone Company at Closter, New Jersey.

C. M. Hebbert talked to the Mathematics Club at Ohio State University on



Honorable Mention for Excellence

In the presentation of Safety for general appeal of editorial contents and for attractiveness in physical make-up is hereby awarded to

Bell Laboratories Record

in the Employees' Magazine Contest conducted by the Employees Publication Section of the National Safety Council during the Year 1940.

UNIVERSAL SAFETY Class I

President National Safety Council

Managing Director National Safety Council

Chairman of the Judges Committee

October 9 on the subject *Variation of Cable Loss With Temperature — Some Applied Mathematics*. He also talked on the same subject to a group of upper classmen and members of the mathematics and physics departments at Miami University, Oxford, Ohio, on October 14.

At the request of the National Broadcasting Company, the New York Telephone Company and the Laboratories have provided special television circuits from Madison Square Garden to the NBC studios in Radio City. The first use of these circuits was during the recent presidential campaign when both President Roosevelt's and Wendell L. Willkie's appearances in the Garden were televised. C. N. Nebel and D. S. Barlow were responsible for circuit arrangements during these speeches.

During the month of October, F. E. DeMotte, B. A. Fairweather, G. H. Huber and V. M. Meserve worked on the Minneapolis-Stevens Point coaxial terminal installation.

J. F. Wentz was at the Point Breeze Plant of the Western Electric Company for two days in connection with their studies of coaxial cable transmission characteristics.

At Philadelphia, C. N. Nebel, M. E. Strieby, A. F. Mott and C. L. Weis made experiments on an experimental circuit for television transmission from Franklin Field in Philadelphia and discussed the problems involved with representatives of The Bell Telephone Company of Pennsylvania and the Philco Radio and Television Corp.

S. Doba and L. W. Morrison were in Camden in connection with some new measuring equipment used in television testing.

Problems in coaxial amplifier testing were discussed with Western Electric engineers at Kearny by M. E. Campbell, B. J. Kinsburg and P. G. Uppstrom.

The coaxial repeater installation on the new cable from Stevens Point to Minneapolis is nearing completion and many transmission tests are now under way. During October, H. H. Benning, C. F. Boeck, B. Dysart, M. M. Jones and B. H. Nordstrom were engaged primarily in testing the line-up and equalization of the Stevens Point-Minneapolis coaxial system. K. E. Gould, G. B. Engelhardt, and T. M. Odarenko were engaged in making special impedance measurements required in connection with television tests which will be scheduled for next spring.

At various points along the New York-Philadelphia coaxial cable M. M. Bower, J. J. Strodt and J. M. West investigated the cause of certain intermittent troubles.

A demonstration of frequency-modulated television signals was observed by P. Mertz, W. T. Wintringham and N. F. Schlaack on a recent visit to Camden.

Miss C. Mattice appeared before the Board of Appeals at the Patent Office relative to an application for patent.

R. J. Guenther was at the Patent Office during October to attend hearings before the Board of Appeals and Primary Examiner in interference proceedings.

L. E. Coon attended the 29th National Safety Congress and Exposition held in Chicago from October 7 to 11.

"Information" in Less Space

By A. C. GILMORE
Manual Equipment Development

IN THE larger cities, where there are many central offices, "information" traffic is handled at one or more centralized information bureaus, where a group of "information" operators serve subscribers of a large number of offices. Some years ago the No. 3 information desk* was designed for this sort of service, and has come into fairly wide use. Since it was intended primarily for very large centers, such as New York and Chicago, it was designed to accommodate at each position four large local record binders open on reading shelves before the operators as well as a number of smaller toll and auxiliary record binders in directory racks. Although modified arrangements for two information binders were later made available, they did not permit as great a reduction in the space requirements as desired because of the basic section design of the information desk.

There are, however, many multi-office cities with centralized information service that require only one, or at most two, local record binders open before the operators, and such bureaus also require fewer toll and auxiliary binders. They have relatively small desks that do not contain many of the desirable features of the No. 3 desk. It is in these smaller centers that floor space requirements

*Record, *March*, 1930, *p.* 328.

are more frequently a controlling factor, and even the modified No. 3 desk might be larger than could be conveniently accommodated. It seemed desirable, therefore, to design a new information desk framework to secure the floor space economies that the smaller number of records permits, and still retain the advantages of the circuits of the No. 3 desk. Such a desk could then be used to replace existing ones as occasion demanded. As a result the No. 6 type information desk has been developed. It uses the same key equipment and circuits as the No. 3, but provides a simpler and smaller desk framework, and permits easier installation procedures.

The new desk is designed on the basis of using one or two large local information binders per position. In the one-book form it is known as the 6A desk, and in the two-book form as the 6B, the latter requiring more floor space than the 6A but less than the two-book No. 3 desk. An installation of the 6A desk in Dallas, Texas, is shown in the photograph at the head of this article. Key and lamp equipment is mounted in the two opposite faces of a rectangular turret at one side of the position. This arrangement provides a double-sided desk with two operators. A sloping shelf on each side provides for the single information binder, and the level space between the key equipments may be used for a toll directory rack when required. In place of the wooden upright partitions formerly used between operators, a new transparent material is employed that has certain minor advantages over the wood.

The 6B section, shown in Figure 1, is like the 6A except that an additional sloping shelf is provided for each operator in the space between the key equipments, and it is for this reason that the 6B is somewhat larger than the 6A. Where toll and auxiliary records are required, they will be placed in a toll directory rack mounted on top of this added sloping section. When this is done, the lamps used to call the supervisor, shown on top of the key cabinets in the photograph at the head of this article, will be extended above the toll directory racks on pipe standards. The additional upper sloping shelf of the 6B desk provides room for a second local information binder.

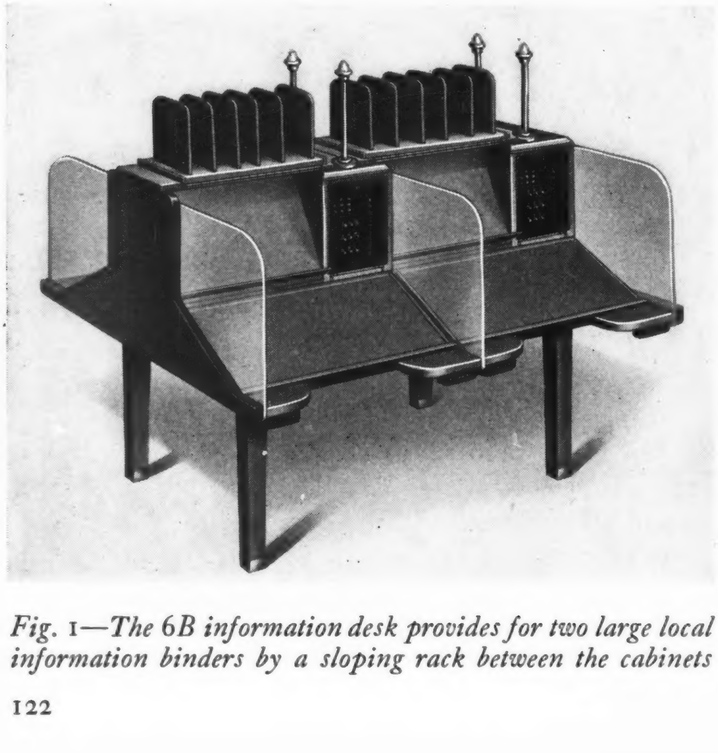


Fig. 1—The 6B information desk provides for two large local information binders by a sloping rack between the cabinets

The supporting structure for both of these desks is the framework and legs of a commercial flat-topped table. In a new installation, these lower units are all set

in place first, and a metal cable rack is carried along them just below the top. The upper units are then put in place beginning at the end of a desk line-up farthest from where the cables enter. As each upper unit is put in place, the cables attached to the key panel are laid along the rack, as indicated in Figure 2. This simplifies the installation, since there is a minimum of work that must be done from underneath the desk top.

These new desks require less space than the corresponding No. 3 desks, and this fact, together with the simpler installation, reduced cost and the desirable operating and service features of the circuits of the No. 3 desk, makes them attractive for all but the largest multi-office cities.

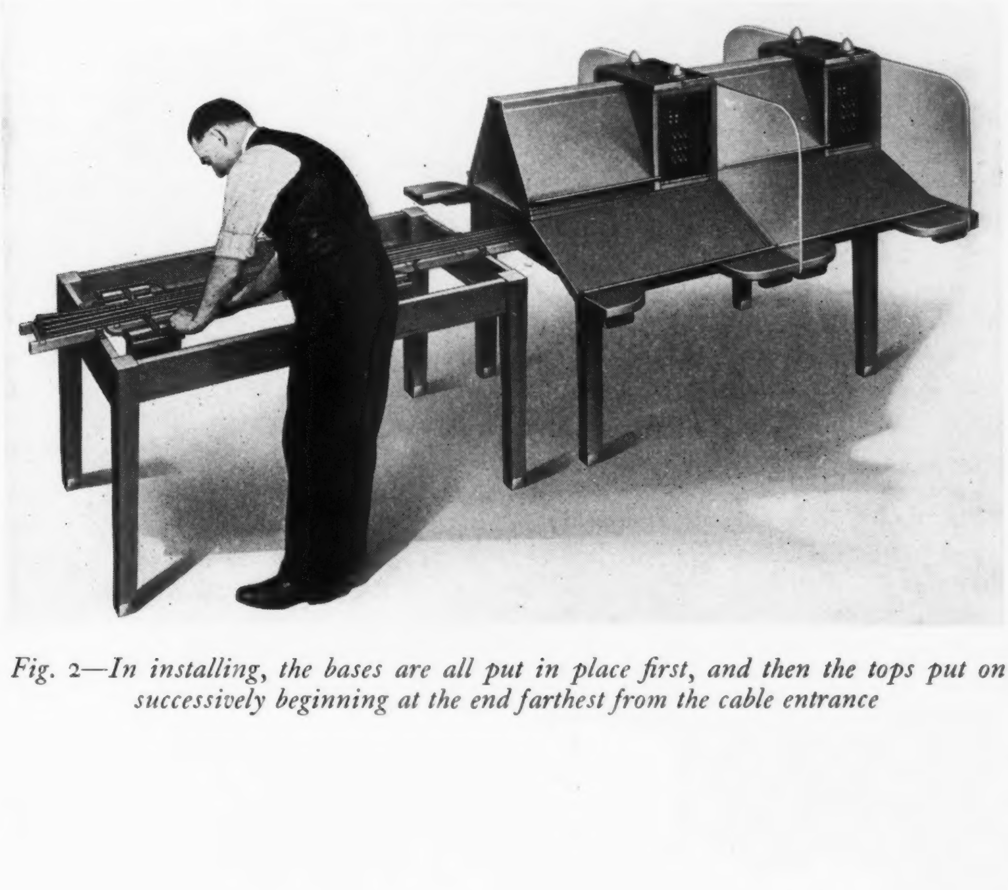


Fig. 2—In installing, the bases are all put in place first, and then the tops put on successively beginning at the end farthest from the cable entrance

Carrier and Pilot Supply for the J2 Carrier System

By L. R. COX
Carrier Telephone Development

THE J2 carrier system provides twelve voice channels in each direction in the frequency range between 36 and 143 kc. As with all the broad-band systems, twelve voice channels are modulated with twelve carriers at the transmitting terminal so as to lie between 60 and 108 kc, and then by two group modulations the 12-channel band is translated to the frequency position it will occupy on the line. To help in reducing cross-talk, four frequency allocations are provided so that when several systems are transmitted over the same pole line, the channels of various systems will be different from each other. The carrier supply system must provide not only the twelve carriers required for the basic channel modulations, but also those needed for the group modulations for each of the four line allocations. In addition each system employs two pilots to control the net transmission loss, and the carrier supply system must also provide the pilot frequencies needed.

The four frequency allocations are known as the NA, NB, SA, and SB. For the west-east direction, the NA and NB allocations are alike, as are the SA and SB; but for the east-west direction, all four are different. The frequency positions of these allocations and the modulating carriers required are graphically shown in Figure 1. Corresponding demodulations take place at the receiving terminal. All allocations use the same frequency, 340 kc, for the first stage of group modulation. For the second modulation, two carriers are required for the W-E allocations, and four for the east-west allocation. These are 364 and 484 kc for the west-east allocation and 306, 308, 541 and 543 kc for the east-west. Seven carriers are thus required for the group modulations in addition to the twelve required for the channel modulations. The positions of the sidebands with respect to the channel carriers are indicated in the conventional manner. In the basic group they are lower sidebands, and the first group modulation retains them in this position. The second group modulations employing carrier frequencies above 448 kc, however, in-

TABLE I

GROUP CARRIER FREQUENCY SOURCES

Harmonic of 4 kc	*Harmonic of 5 kc*	*Derivation*
79th	2nd	316 − 10 = 306 kc
77th	None	308 kc
85th	"	340 kc
91st	"	364 kc
121st	"	484 kc
67th × 2	1st	2 × 268 + 5 = 541 kc
137th	1st	548 − 5 = 543 kc

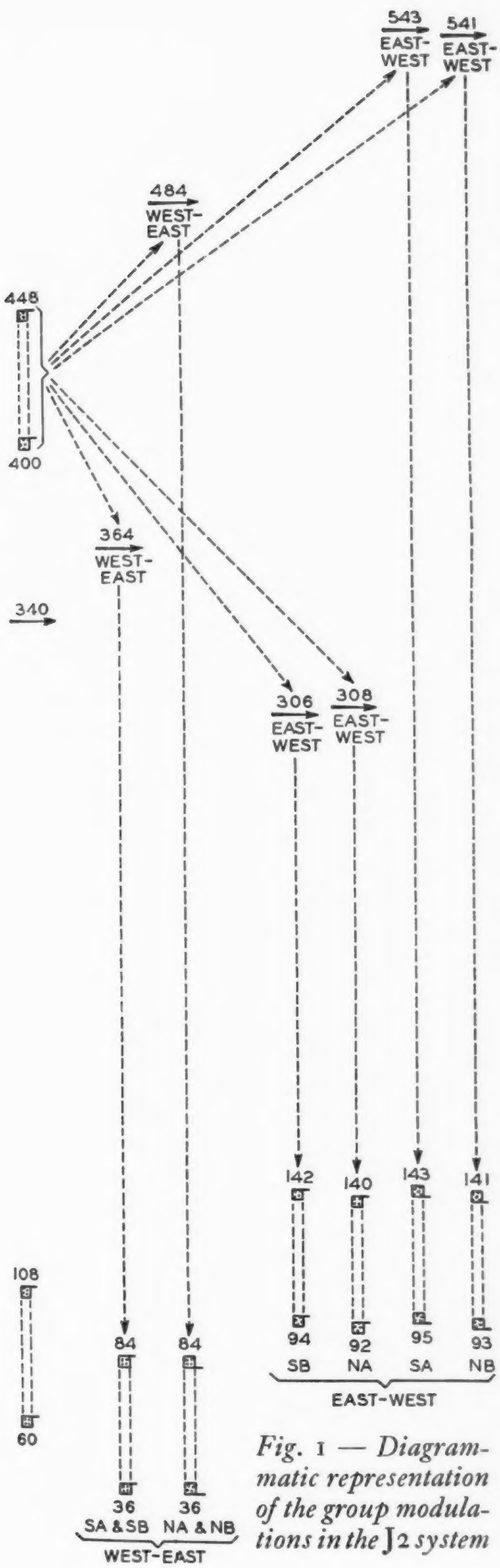


Fig. 1 — Diagrammatic representation of the group modulations in the J2 *system*

vert the position of the sidebands with respect to those employing carriers below 400 kc.

As with the type-K and other broad-band carrier systems,* most of the carriers are supplied by a 4-kc oscillator and a harmonic producer. From this source, filters pick out twelve frequencies at 4-kc intervals from 64 to 108 kc inclusive, and these are used to modulate twelve voice channels to form the basic group. This derivation of all the carriers from a single source is very advantageous because regardless of slight variations in the frequency of the basic source, all the channels retain the same harmonic relationship. Also, any variation in frequency can be corrected by an adjustment of one oscillator, while if a separate oscillator were used for each carrier frequency—a total of nineteen is required for the J2 system—each oscillator would have to be adjusted separately. The advantage of the harmonic generation of carriers from a single source is of particular importance in such a system as the J2, where the modulating frequencies are high with respect to the line frequencies. Under these conditions, and using independent oscillators for each carrier, the variations of all the oscillators may add up and thus give a net variation at the line frequency that is much larger than the variation of any one oscillator. With carriers all derived harmonically from a single source, however, the variation in the final line frequency, expressed in per cent, is always the same as that of the oscillator from which the carriers were derived.

The 308, 340, 364, and 484-kc carriers are all odd harmonics of 4 kc, and are selected by filters and suitably amplified. Filters, amplifiers, and

*Record, *April,* 1937, *p.* 242.

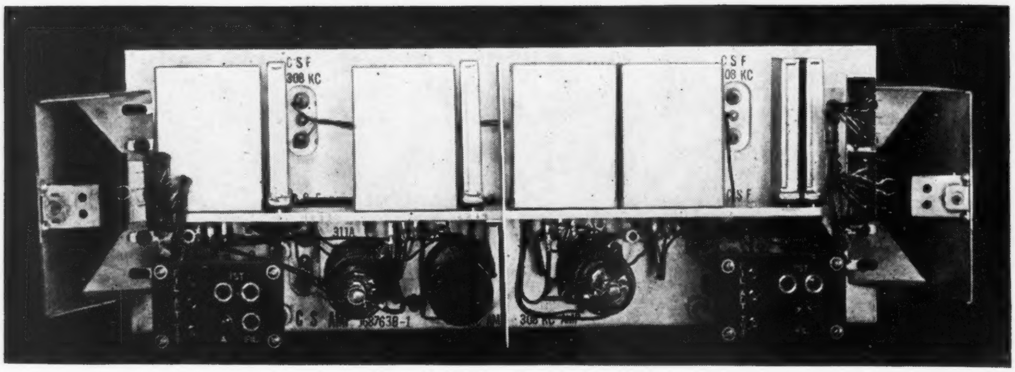


Fig. 2—Carrier-supply panel for 308 and 340 kc

other equipment for two carriers are mounted on a single panel as shown in Figure 2. The three other frequencies, 306, 541, and 543 kc, however, are not harmonics of 4 kc, and to secure them, a 5-kc oscillator is provided and used to modulate a harmonic of 4 kc. By modulating 548 kc, the 137th harmonic of 4 kc, with 5 kc, the difference frequency of 543 kc is readily obtained. For the 541-kc carrier, 268 kc—the 67th harmonic of 4 kc—is modulated with 5 kc. The products of any such modulation include, besides the sum and difference frequencies, the sums and differences between the multiples of 268 kc and the odd multiples of 5 kc. Twice 268 plus 5 gives the required 541 kc. To secure the 306-kc carrier, the connections of the 5 kc and of the 4-kc harmonic to the modulator are interchanged, so that an even harmonic of 5 kc will be available. The 79th harmonic of 4 kc—316 kc—minus twice 5 kc yields the desired 306 kc. The derivation of these various carriers is indicated in Table I.

A single-tube, fork-controlled oscillator is used to supply the 5 kc. This is quite similar to the 4-kc supply. The circuit arrangement is shown in Figure 3. A steel fork, operating in a vacuum in a sealed container, has an electromagnetic coil near each prong. One is connected to the plate and the other to the grid of the vacuum tube. The coils are shunted by condensers to tune their inductance, and the condenser shunting the grid coil is made adjustable to give control of frequency over a small range but it is not expected that adjustment will be needed except at long intervals. A varistor is connected across the plate coil to limit the voltage. The complete oscillator unit is mounted on a small panel, the front of which is shown in Figure 4; the fork unit and a few other elements are on the rear of the panel.

The modulating circuit with which this oscillator is used is shown in Figure 5. A copper-oxide varistor type

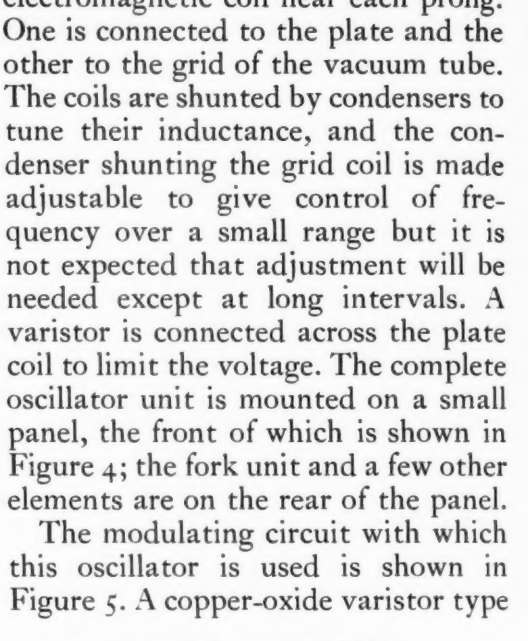


Fig. 3—Schematic of 5-kc oscillator used to modulate odd harmonics of 4 kc to obtain some of the group carriers

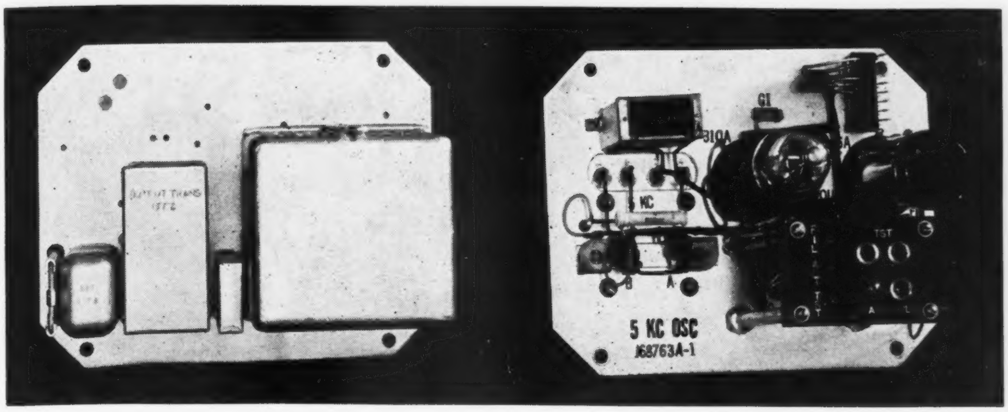


Fig. 4—The 5-kc oscillator panel used to secure group carriers

modulator is employed. The circuit connections are the same for both 541 and 543-kc carriers; only the filters are different. For the 306 kc, the arrangement is similar, but the connections of the 5-kc oscillator and the 4-kc harmonic are interchanged for reasons already stated. In all cases amplifiers follow the filters.

Besides these seven carriers required for the first and second group modulations, six other frequencies are

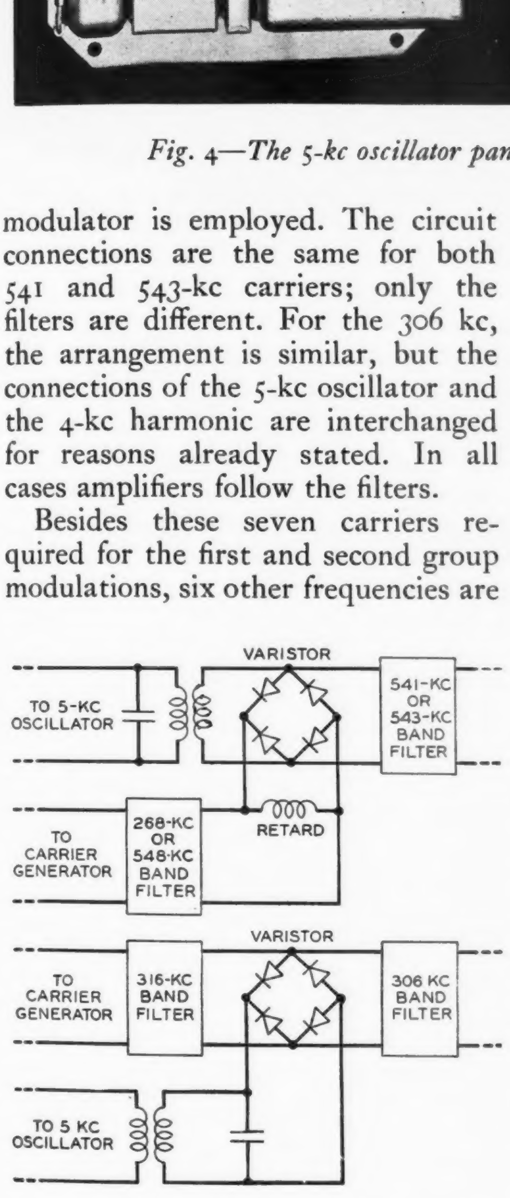


Fig. 5—Block schematics of the two modulating circuits used to obtain carriers of 306, 541, *and* 543 *kc*

needed to serve as pilots. For the west-east transmission, the pilots are at 40 and 80 kc on the line for all allocations, and for east-west transmission they are 92 and 143 kc for all allocations. For all west-east allocations, 40 and 80 kc are the positions that would be occupied by the channel carriers of 64 and 104 kc if they were transmitted. All carriers are suppressed in the channel modulating circuit, however, and these two frequencies are resupplied as pilots.

Although the carriers are suppressed in the channel modulator, there is always a small amount of carrier leak. The effect of this leak on the level of the pilot could readily be allowed for, but if the frequency of pilot and carrier should differ somewhat, beat frequencies would result, and would be objectionable. Such beating is avoided by using the same 4 kc as source for both carrier and pilot. It is necessary, however, that the level of the pilot be accurately constant, while slight variations in the level of the carrier are unobjectionable. This constant level of the pilot is secured by using a second oscillator whose frequency is locked by the 4-kc harmonic and whose output is stabilized by a lamp-resistance bridge in

the feedback path. The circuit in simplified form is shown in Figure 6. As the output increases, the lamps heat up, and the bridge approaches the balanced condition, decreasing the positive feedback. Equilibrium is reached when the loss in the lamp-resistance bridge equals the gain in the amplifier. In the vicinity of the balanced condition, the circuit is very sensitive and maintains a constant output with considerable accuracy. Variation in the level of the locking frequency or in the gain of the amplifier produces very little change in the output since a small change in the resistance of the lamps in the nearly balanced bridge produces a relatively large change in the loss. A 5-db change in the input or in the gain of the amplifier, for example, results in less than a 0.1-db change in output. One locked oscillator is used for the 64-kc and one for the 104-kc pilot, and their outputs are connected to a single bus that supplies the two west-east pilots for as many as ten systems.

It is desirable to have the pilots for one direction of transmission all at the same frequency on the line so that the same pilot filters used with the regulators can be employed for all frequency allocations. This is easily accomplished for west-east transmission by selecting two of the carrier positions for the pilots because these remain carrier positions for all four allocations. With east-west transmission, however, the carrier positions for the different allocations are staggered, so that if the same pilot frequencies are to be used for all allocations, they must fall outside the transmitted band.

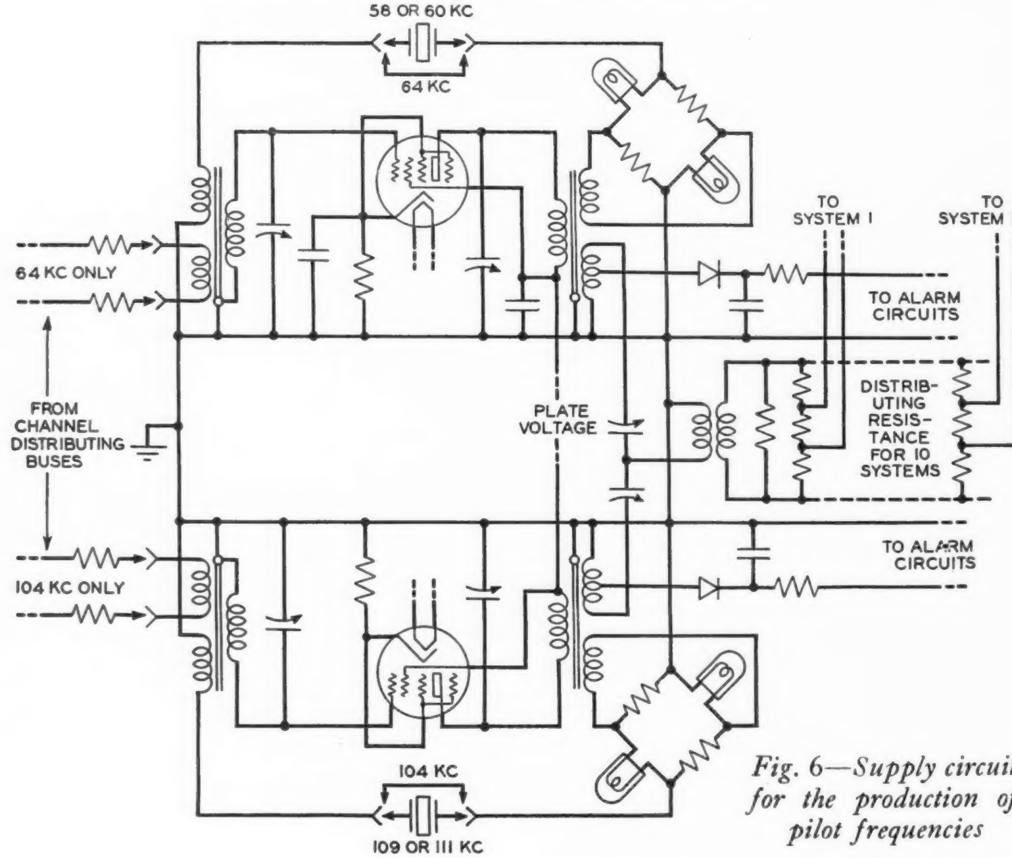


Fig. 6—Supply circuit for the production of pilot frequencies

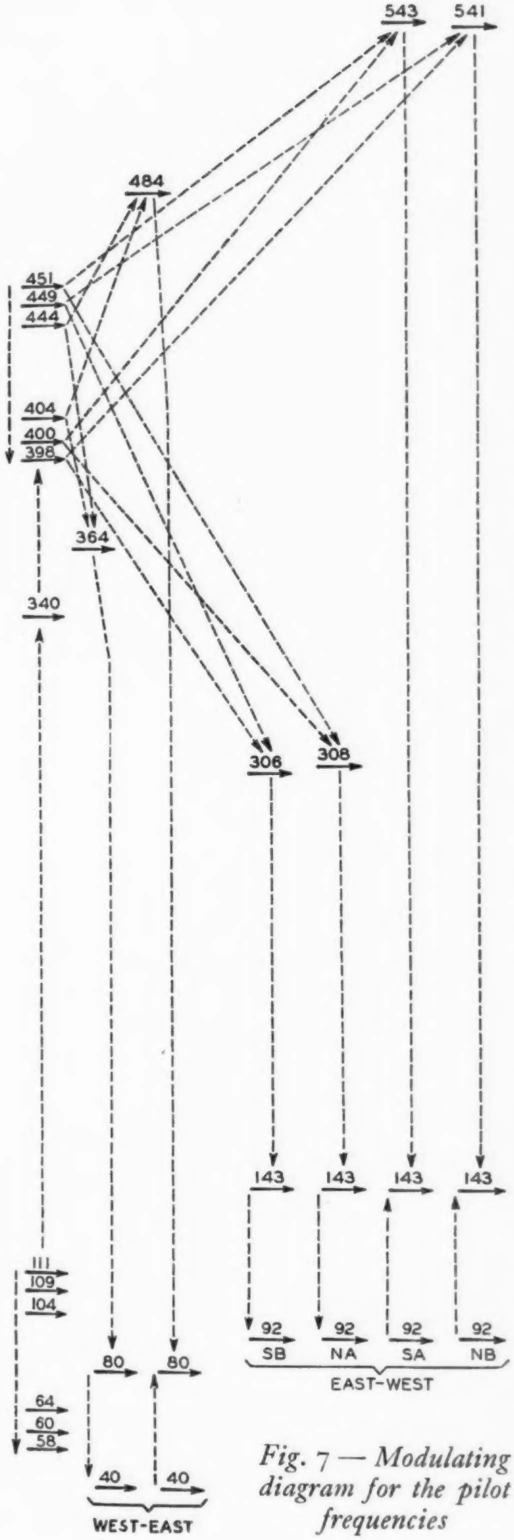


Fig. 7 — Modulating diagram for the pilot frequencies

By selecting pilot frequencies, on the line, of 92 and 143 kc, only two pairs of pilot frequencies before modulation are required. These are 58 and 109, and 60 and 111 kc. Since these frequencies are not normally furnished by the carrier supply, separate oscillators are used. The 58 and 109 are used for the NB and SB allocations and the 60 and 111 for the NA and SA allocations. The oscillators for these pilots are identical to those of Figure 5 except that there is no locking circuit, and instead, a crystal is placed in the feedback circuit to control the frequency, as indicated on the diagram. One such pair of oscillators supply the NA and SA allocations, and one the NB and SB allocations. All these pilots are generated at frequencies suitable for supply to the circuit before the group modulations, being at 58, 60, 64, 104, 109, and 111 kc. The effect of the two group modulations in bringing them to their line positions is shown in Figure 7.

The carrier supply equipment is provided in duplicate, and a transfer circuit is arranged to change to the second supply if the voltage on the first drops below a safe value. Transfer requires only a few milliseconds. An alarm is given whenever a transfer is made so that the cause of the transfer may be investigated, and a different alarm is given in the event of total failure of supply. The pilot supply is not provided in duplicate, but alarms are given whenever the level changes by as much as ½ db.

The arrangement of the carrier supply circuit is in general the same as that used for the type-K system.* Two bays are required for mounting the carrier supply equipment and these supply terminals for ten complete systems, or 120 talking channels.

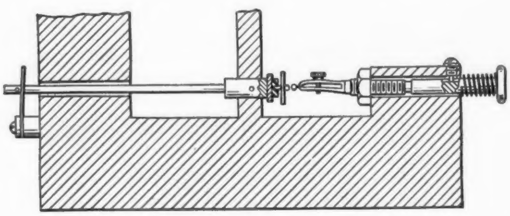
*Record, *July*, 1938, *p.* 365.

Metallic Bridges Between Contact Points

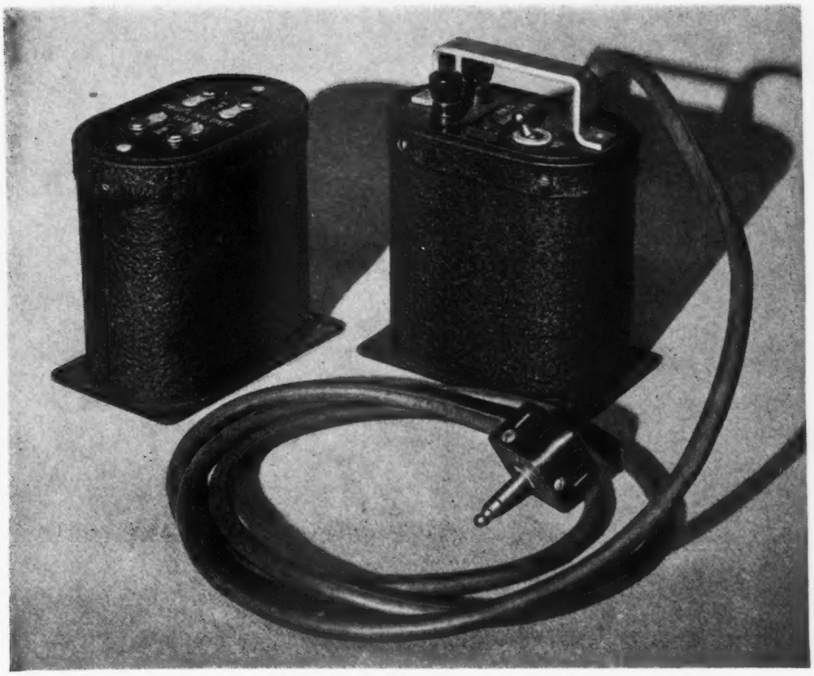
WHEN two electrodes are brought very close together, even under relatively low voltages, particles are torn from the electrodes and may establish a conducting bridge between them. These conducting filaments form at voltages less than the sparking potential and are produced by the large electrical forces which result from the very small separation of the electrodes.

In experiments by G. L. Pearson, bridges were formed between gold, steel and carbon electrodes when separated from 2 to 70 x 10^{-6} cm. The voltage gradients were about ten million volts per centimeter. To determine the point of zero displacement, electrical contact was made between the electrodes. They were then separated a known distance and the voltage between them slowly raised until the bridges formed. This occurred at voltages between 15 and 350 volts depending on the separation. The resistance dropped permanently to a low value at the same time.

Measurements of the temperature coefficient of resistance of the bridges identified them as consisting of the material of the electrodes and changes of their resistance when the electrodes were separated or brought together slightly showed that they can be pulled out and crushed. The separation of the electrodes was controlled very delicately by attaching one of them to a cantilever bar and adjusting it with a micrometer screw. The other electrode of the apparatus was mounted on a fixed support. To insure rigidity, the whole apparatus was cut from a solid block of steel.



Conducting bridges form between electrons when brought very close together even under relatively low voltages



A Coupling Unit for Telephotograph Transmission

By D. W. GRANT
Transmission Apparatus Development

WHEN an unusual event of wide interest occurs, news gatherers are alert to get the information to the newspaper offices as soon as possible. Since pictures are often a very important part of this information every effort is made by the reporter to obtain suitable ones and to send them in without delay. The promptness with which pictures can be supplied from distant points has been greatly increased in recent years by the development of satisfactory telephotograph equipment, and the provision of permanent transmission networks with fixed transmitting points in the more important cities of the country.

For transmitting pictures from other points, provision is made for the connection of telephotograph equipment to leased lines for semi-permanent installations or to regular toll lines for short intervals. In either case, it is necessary to have an arrangement for the connection between the telephotograph equipment and the telephone line which will permit the sending of satisfactory pictures, protect the telephone line from high voltages that may be present in the picture-sending apparatus, and prevent the sending of high signal levels which might cause noise and interference on neighboring telephone lines. Another function required of a satisfactory

connection arrangement is a "holding-coil action," so that when the apparatus is connected across the line, it will draw sufficient current to "hold" the supervisory relay in the telephone office, thus permitting the handset or receiver to be replaced on the switch-hook without releasing the line. This is important because the telephone

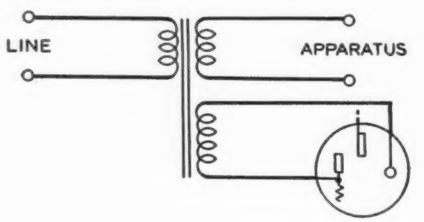


Fig. 1—Schematic of the 105A coupling unit for connecting telephotograph equipment to working telephone lines. The 104A differs from it only in the addition of a switch and plug in place of the line terminals

transmitter, which might pick up sufficient room noise to spoil the picture being transmitted, is thereby removed from the circuit.

To meet the demands presented by the above requirements, two coupling units—the 104A and 105A—have been developed. These units, shown in the picture at the head of this article, provide a simple means for connecting telephotograph equipment to working telephone lines, provide the required holding coil action, and at the same time protect the lines from the possibility of excessive voltages and signal levels.

Electrically these units, shown schematically in Figure 1, are the same. They consist essentially of a transformer with two equal-impedance windings for coupling the transmission apparatus to the line, and a third high-impedance winding connected to a gas-filled tube.

The line winding has sufficiently low resistance to take the required supervisory relay current, and for the protection of the line is insulated from the other windings and from the case sufficiently to withstand surges of 2000 volts.

The gas-filled tube connected to the high-impedance winding is provided to protect the line from excessive signal levels. This tube has a nearly infinite resistance at potentials below about 75 volts. At approximately this voltage, however, the gas in the tube ionizes, and reduces the internal resistance to a very low value. The voltage ratio between the line and tube windings of the transformer is such that this ionizing potential corresponds to a peak voltage on the line of about 1.2 volts, which permits the transmission of slightly over one milliwatt of power into the line without distortion. If, due to improper adjustment of the sending apparatus, an input voltage corresponding to higher power than this is applied to the coupling unit, the voltage across the tube exceeds the ionizing potential and the tube, by virtue of the impedance-transforming action of the coil, imposes a low impedance shunt across the line, thereby limiting the voltage to approximately the critical

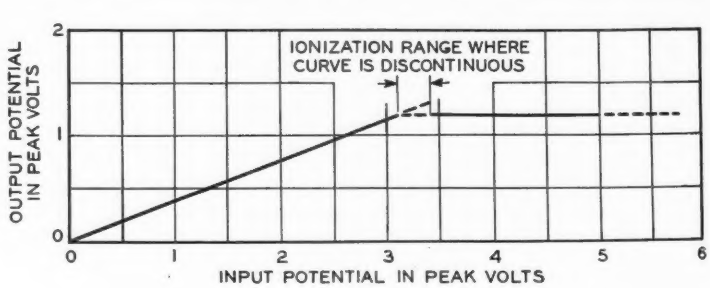


Fig. 2—Output-voltage characteristics of the new coupling unit

value. This characteristic is illustrated in Figure 2, which shows the relationship between generator voltage and line voltage. As may be seen, the output voltage increases linearly with generator voltage up to the point corresponding to the ionization of the tube. This indicates no distortion of the wave form. For higher generator voltages the output voltage increases only slightly. In this range the wave form becomes flat topped due to the peak-limiting effect of the tube.

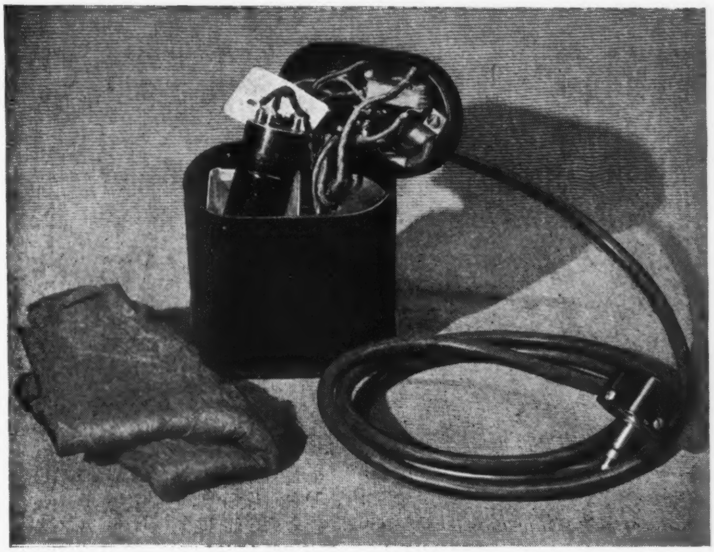


Fig. 3—The 104A coupling unit with cover removed to show the tube case at the left

Although the action of the two units is identical electrically, there is considerable difference physically as may be seen in the photograph. The 104A coupling unit is intended for temporary installations, and is therefore provided with a handle for carrying, a flexible cord terminated in a plug, and a switch in the cord circuit. The plug in conjunction with a jack installed in the line by the telephone company affords a ready means of connection to the line. The 105A coupling unit is intended for permanent or semi-permanent installations, and the line and apparatus windings are brought out to screw-type terminals that are mounted on the cover.

To insure long life, the transformer in both units is sealed to exclude moisture. The tube is mounted inside a small aluminum can which is, in turn, assembled in the larger case with the coil, and the connections between the coil and tube are made by means of the flexible leads with which this tube is provided. The cover of the 104A unit is readily removable so that if necessary the tube may be replaced. This unit with the cover removed is shown in Figure 3.

The development of these units has been a factor in increasing the usefulness of one of the newer types of service offered by the Bell System and available for the use of the press.

Measuring the Air Flow of Small Fans

THE ventilating fan in a telephone booth rotates slowly to assure quiet operation, and it is required to develop an air stream of such low velocity and low noise level that a special set-up had to be made in the Laboratories to measure it; also a stringent vibration requirement must be met.

In the tests a three-inch anemometer is mounted in front of the fan and twelve inches away from it. Measurements are made opposite the center of the fan and at one-inch intervals in four directions along a vertical and horizontal line which intersects the fan's axis. The anemometer is moved outward until the air velocity becomes too small to measure accurately.

The volume of air propelled by the fan per minute may be found from the anemometer readings by dividing the cross-section of the air stream into rings one inch wide and concentric with the axis of the fan. The area of each ring multiplied by the average of the four anemometer readings for that ring gives the air flow through it and the sum of these values the total air flow. The rate of rotation of the fan is measured with a stroboscope by determining how many flashes per minute make the blades of the fan appear to stand still. Ordinarily, the fans that are provided for telephone booths circulate from 175 to 350 cubic feet of air per minute.

To test for vibration the fan is mounted on a platform on which rests a vibrometer. By moving the vibrometer about on the platform the vibration in different directions is found.

Contributors to this Issue

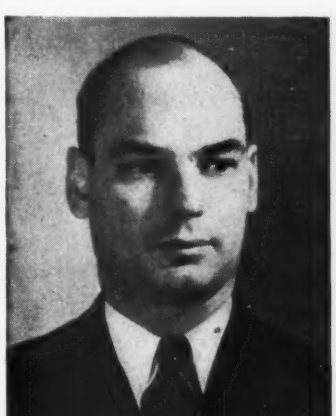
Leslie R. Cox graduated from Purdue University in 1922 with the degree of B.S. in Electrical Engineering, and then joined the Western Electric Company at Hawthorne. After completing the students course he was engaged in writing installers' specifications for panel machine-switching exchanges. After a few years outside of the Bell System, he joined the toll development group of the Bell Telephone Laboratories in 1929. Since then he has been engaged in the development of carrier terminals for broad-band systems. His principal interest has been modulators and their carrier supply.

C. D. Owens received the degree of A.B. in Physics from Indiana University in June, 1928, and immediately joined the Technical Staff of the Bell Telephone Laboratories. As ~~a member of~~ with the Transmission Apparatus Department he ~~has been~~ engaged in the development of condensers, loading coils, retardation coils, and compressed magnetic powder cores. During this period, he took part-time graduate work at Columbia University and received an M.A. degree in Physics from this university in 1936.

D. W. Grant received the degree of B.S. in electrical engineering from Kansas State College in 1928. Coming at once to these Laboratories, he joined the transformer group in the Apparatus Development Department, where he has been engaged in the development of audio-frequency transformers for use in the telephone plant and in specialty products apparatus.

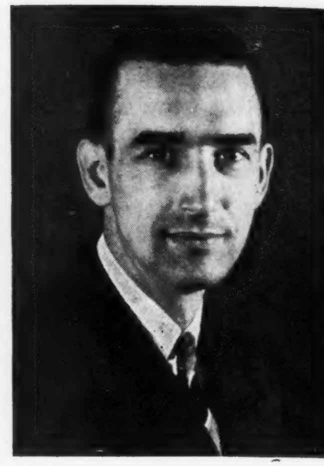
K. G. Van Wynen came to the Development and Research Department of the A. T. & T. Company after receiving the E.E. degree from Cornell University in 1925. Until 1927 he was associated with a group working on program transmission problems. From 1927 to 1929 his work was on inductive interference in connection with railway electrification. Since 1929 he has been concerned with the rating of transmission performance. During this interval he has been principally interested in the design and construction of circuit arrangements used in field and laboratory tests. Mr. Van Wynen also attended the Brooklyn Polytechnic Institute where he received the M.E.E. degree in 1933.

L. R. Cox



C. D. Owens

D. W. Grant



K. G. Van Wynen A. C. Gilmore G. L. Pearson

A. C. Gilmore joined the Laboratories in 1916 and became associated with the Materials Inspection group. Shortly after, however, he transferred to the Systems Department and for a number of years was engaged in equipment drafting. In 1923 he joined the Equipment Development group where he was first concerned with the analyzation of Hawthorne orders and later with trial installations. At the present time he is engaged in the development of equipment for central offices such as that he describes in this issue.

Gerald L. Pearson, who describes thermistors in this issue of the Record, began the Laboratories' study of these devices some five years ago. Entering our Physical Research organization in 1929, he had behind him undergraduate work at Willamette (A.B. 1926) and graduate study at Stanford (M.A. 1929). His initial assignment was to study thermal noise in conductors, shot noise in vacuum tubes and carbon noise in microphones. One of these studies has been accepted by Columbia University as a thesis for the doctorate of philosophy. A collateral investigation of thermo-sensitive materials grew eventually into a project under Mr. Pearson's direction, from which have come a number of present and prospective uses for thermistors in the Bell System.